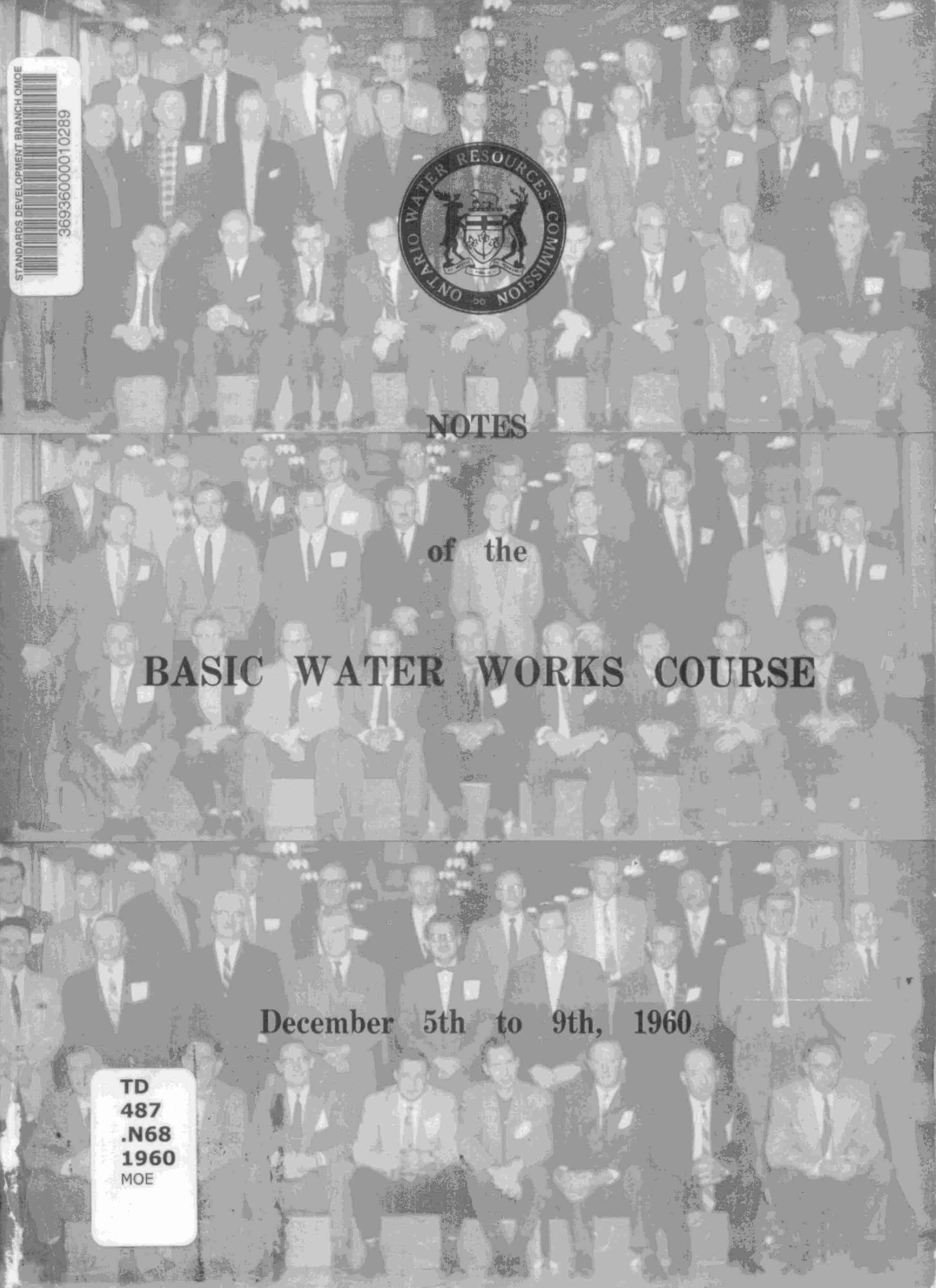

NOTES

of the

BASIC WATER WORKS COURSE

December 5th to 9th, 1960

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BASIC WATER WORKS COURSE

DECEMBER 5th to 9th, 1960

ONTARIO WATER RESOURCES COMMISSION

BASIC WATER WORKS COURSE

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WATER WORKS OPERATORS' COURSE
ONTARIO WATER RESOURCES COMMISSION
DECEMBER 5 - 9TH, 1960

Introductory Statement by Dr. A.E. Berry, General Manager, OWRC.

The start of this course brings into being a plan which has been developing for a number of years in Ontario. Some attempts were made previously to provide instruction for water works operators, but lack of adequate facilities postponed any definite action. The completion of this modern laboratory and lecture hall makes it possible to proceed on this program. It is gratifying that there is, at this first formal course of instruction, a large number registered from all parts of the province.

The Ontario Water Resources Commission

This new program results from two measures. One is a recommendation of the Canadian Section, AWWA, that courses of instruction be set up in all provinces to train water works operators, and the other is the desire of the Ontario Water Resources Commission to assist in the most efficient operation of all water works plants in this province.

At the outset, it is well to note something about the organization of the Ontario Water Resources Commission, and how it is related to the Health Department, and to other agencies in the province. Formerly, the supervision of water works

systems in the province came under the Sanitary Engineering Division of the Ontario Department of Health. When the Water Resources Commission was established in 1956, and the legislation later amended in 1957, this supervision was transferred from the Health Department to the OWRC. The Commission operates under The Ontario Water Resources Commission Act, which legislation is modified substantially from that contained in The Public Health Act before the transfer. The present legislation gives the Commission wide authority to deal with water works systems. The Commission maintains a staff of well trained personnel, who are the advisers to water works groups at all times throughout the province. These men are specialists in a variety of activities relating to water works. Those present at the course will hear from many of them, and you will learn more about the activities of the Commission, and how the staff deals with these various problems. It is well, under these circumstances, that each one registered at the course be familiar with the organization of the Commission, and the different officials with whom they will be dealing.

The Objective of the Course

It is proper, at the outset of this course, that objectives be defined, so that each person will understand what is expected of him, and what type of training he is likely to secure.

The first requirement is to train operators in the fundamentals of plant operation. No effort will be made to make

engineers or commissioners or other like specialists, but rather to attempt to train all who are here to be good effective operators. Accordingly, fundamental subjects will be discussed in this first course, and advanced courses of training will come later.

This is a working course in which each man will be expected to apply himself diligently, and to acquire as much as possible from the lectures that are to be given, and from the demonstrations which will take place in this laboratory. It may be inconvenient for some to listen hour after hour to lectures, especially when they have not been accustomed to this for such a long time.

The length of the courses of instruction will be determined, but it is anticipated that three such courses will be required before certification is attempted. Thus the first course will be general in its application, and others will be more specialized, such as providing information on purification processes, distribution systems, deep wells, etc.

It is to be noted, also, that this course is not given in preparation for a licensing system, similar to what is in force in some parts of the United States, but rather this is to provide a qualification which will be recognized throughout the province. Each person attending the course should have had some experience in water works operation. If much experience has been had, some of the material in the first course will not be new, but repetition should not be objec-

tionable. The objective in this training is to serve the needs of the water works operators. It is hoped that criticism and recommendations will come forth, and that there will be a good discussion at all times on the subjects dealt with. You are asked to question the instructor freely, and to make certain that you obtain as much information as possible in the allotted time.

Subjects of the Course

Your attention is directed to the time table to give you the list of the subjects to be covered. It will be seen that there is an emphasis on operating problems, and the provision of background information. All of the instruction in this first course, with the exception of two hours, will be given by the staff of the OWRC. The Commission is grateful for the cooperation that is being provided by Metropolitan Toronto and others. Some laboratory tests will be carried out in this first course, and more will follow in later ones. There will be a discussion period at the end of each lecture, the value of which will depend upon the number of questions asked.

Future Courses and Examinations

It is obvious that one course of instruction extending over a week will not be sufficient to provide broad fundamental knowledge for water plant operators. Accordingly, it is proposed that there be three courses with each of the subsequent ones being more advanced. It is hoped, also,

that refresher courses can be brought on periodically at the conclusion of these training courses, so that each person will be continuously in contact with current information. An examination will be held to test the knowledge of the student. It will be apparent to all that the municipality sending an operator to this course has made an investment. The course must justify itself, and the operator must acquire enough information to justify the time and expense.

Certification of Operators

In these days for competition for knowledge, it is pertinent that the operator who has obtained this training should be recognized in some tangible manner. Certification appears to be the best procedure. It is hoped that the certificates issued by the Commission to those who have obtained this qualification will be recognized throughout the municipalities of this province, and that they will become increasingly important, regardless of where the operator may work. The Commission proposes to emphasize the significance of these certificates, and to publicize the qualifications of those who have attained this standing. It is hoped, also, that others in related fields will receive similar training, such as sewage works operators, plumbers, etc.

Reading and Self-Training

This course is intended to act as a stimulus to greater

knowledge. It would be folly to think that all that is needed by an operator can be secured in the short time that he is taking this training. It is necessary to follow this up by the reading of books, magazines, and other publications. Continuous study is imperative in these days of rapid advances in the water works field.

The Follow-Up Program

The foregoing will serve, it is hoped, to indicate to the operators registered at the course the objectives of this training, and the proposal for certification. This may be supplemented by a number of things which can be done by the OWRC, and by the operators themselves. It is obvious that many things can be done if the operator desires to become efficient in his own field,and to act as a leader. Some of the things that may be done to assist in this are as follows:

The Commission intends to publish, as soon as possible, the lectures given at this course. This material will serve as a reference, and each operator is urged to study the contents, and to familiarize himself with this information.

The operator can also acquire valuable information through attending area conferences, which are now being set up throughout the province to assist operators in their day-to-day problems. These one-day meetings can deal effectively with many of the problems which occur in the operation of water works plants. The operator can also acquire valuable information by becoming a

member of the Canadian Section, AWWA. Many municipalities now hold corporate memberships, and the journals are available for study. If there is no membership in the municipality at present, it would be profitable for the operator to join that association.

Advantage can also be obtained through acquiring a set of good books on water works. There are many of these published. It is hoped that the Commission can prepare, in due course, a list of recommended reading for operators. It is also hoped that some regular publication, such as an operators' news, can be made available to bring to the attention of the operators some of the newer features in this field. Other courses will be announced later, and time tables will follow.

One of the main features about any course of instruction is the incentive which it creates in the minds of the students for acquiring greater knowledge. A vast amount of knowledge can be acquired today, if the individual has enough desire to do so. This course is merely an attempt to assist him towards attaining that objective.

PUBLIC HEALTH REQUIREMENTS OF WATER TREATMENT

by

G. M. Galimbert

Director - Sanitary Engineering - OWRC

An Address To
The Ontario Water Resources Commission
Basic Water Works Course
Toronto, Ontario
December 5, 1960

PUBLIC HEALTH REQUIREMENTS OF WATER TREATMENT

G. M. Galimbert

Director - Sanitary Engineering - OWRC

Water is one of man's most vital requirements. It is paramount therefore that all public health aspects be given consideration in water protection and treatment, if one is to be assured of a water that will meet all established standards of quality. In order to be wholesome, water must be (a) uncontaminated and of a quality that will not cause disease to consumers; (b) free from excessive amounts of mineral and organic matter; and, (c) not contain any material of a poisonous nature.

FIRST REQUIREMENT - MAINTENANCE OF ESTABLISHED STANDARDS

The major public health requirement of water treatment is that the quality of the product must meet standards that were first established in 1914 by the U. S. Public Health Service and which have been amended in co-operation with the American Water Works Association, the American Chemical Association and other organizations in the passing years. The progress in water treatment is indicated in the revisions that have taken place in the standards through the years to meet three major kinds of requirements: (1) bacteriologic; (2) physical: and (3) chemical.

Bacteriological standards were the most important at the time of the creation in 1914. At that time, danger from bacterial contamination was the major problem to the industry. The provision of filtration and then chlorination with many variations in those treatments has minimized the enteric waterborne infections such as

typhoid fever, paratyphoid fever and dysentry that were the cause of grave concern in the days before the availability of such treatments and, in particular, chlorination. The fact that communities have been relatively free of attack for generations, however, does not eliminate the possibility of a major waterborne epidemic. There will always be the need for continued, responsible supervision at any water works plant to assure that the quality of the water is not affected and that there will be no return to the waterborne epidemics of another era. The first public health requirement in water works treatment continues to be responsible supervision to assure that proper standards are reached to maintain the quality of the water.

SECOND REQUIREMENT - KNOWLEDGE OF POLLUTION ENDANGERING PLANT

There is a second requirement that has become more important in recent years as communities become increasingly industrialized. Natural water sources have become more vulnerable to pollution from domestic and industrial wastes. The job of keeping our drinking water safe has become an increasingly vital and difficult task. It is recognized that the war against pollution is in progress but it cannot be said that the battle has been won. In fact, it is only beginning. In the meantime, municipalities pour untreated or partially treated sewage into the streams and industry dumps a variety of chemical contaminants that is ever-changing. The water works and particularly those in the larger and more populated areas are confronted with new and perplexing problems that were not present a few years ago. If they are to operate properly, or at all,

it is essential from a public health standpoint, that their personnel know the sources of contamination that are or may become a danger to the quality of the water in their plant. The amount of close supervision required in operating a plant is materially increased in those areas that known sources of contamination are present. A second public health requirement, therefore, is that the personnel in the water works plant should know the sources of contamination that endanger their operation and should have every facility available to meet pollution if it reaches the plant.

THIRD REQUIREMENT - TRAINED WATER WORKS PERSONNEL

Another public health requirement is that the operation of the water supply system should be under the supervision of responsible personnel whose qualifications are assured by a recognized authority. While this is desirable, it must be agreed that this standard cannot always be secured, particularly in the smaller plants that have only chlorination treatment or none at all. The person in charge of treatment in a modern sized or large filtration plant should be one that has some knowledge in the fields of chemistry and bacteriology of water if the finished product is to be turned out to the best possible standard. In many plants there is a chemist to supervise the treatment and an engineer to take charge of mechanical details to assure proper operation. In smaller plants the need for a person with a detailed knowledge of chemistry and bacteriology is not as essential but some knowledge in those subjects is of value in any plant to enable the operator to turn out a safe water with the facilities that he has available. That is one of the reasons for

water plant employee training courses that are given by many departments of health and other agencies. Their purpose is to acquaint operators, particularly in smaller and medium sized plants, with methods and treatments that can be used to assure a safe water at all times, as it has been recognized that public health requirements demand responsible trained personnel in water works plants regardless of their size.

FOURTH REQUIREMENT - PROPERLY DESIGNED PLANTS

Another public health requirement is that the water works plant should be so designed that the operator can turn out a satisfactory quality water at all times. It is recognized that not all water works plants have been properly designed. Some have been built to meet the economy of the community rather than to meet general recognized water works or public health standards. There is, therefore, a vast variety ranging from the modern filtration plant with correct raw water conditioning through several filter plants with either inadequate or no raw water conditioning or insufficient filtering capacity to the plant that is dependent on chlorination alone for treatment. The general public is not aware that the water works in one community has far better facilities than one in another municipality but the experienced and competent operator must evaluate his plant and its advantages or shortcomings so that he may meet the problems that materialize from time to time. A properly designed water works is therefore another public health requirement in the provision of a safe water supply.

SUMMARY OF PUBLIC HEALTH REQUIREMENTS

The major requirements from a public health standpoint can therefore be listed as follows: (1) the quality of the water must meet the standards established by the public health and water works authorities; (2) the personnel should know the sources of contamination that endanger their water works and have the knowledge and facilities available to meet the danger of pollution; (3) responsible trained personnel should be in charge of water plants, and (4) the plants should be properly designed. More details can now be stated relative to each of these requirements.

STANDARDS TO BE MAINTAINED AT WATER WORKS PLANTS

The standards that must be maintained in a water supply are (1) bacteriological; (2) physical; and (3) chemical. Most operators are more conversant with the bacteriological requirements than the others, as through the years more stress has been placed on such standards by health authorities. It has been the goal in this field in Ontario to have zero organisms of the coliform group reported in treated water samples. This is more stringent than the recognized standard that permits that in all standard ten millilitre (10ml) portions examined during a month, not more than ten (10) per cent should show the presence of organisms of the coliform group. It would appear, therefore, that our requirements have been stringent in view of the fact that the recognized standards do permit some tolerance.

SAMPLING OF WATER

It is naturally essential that regular samples be submitted for

bacteriological analysis if one is to judge the quality of the water properly. There is a recognized specified number of samples that should be submitted monthly based on the population served and this is indicated in the following table:

POPULATION SERVED	NO. OF SAMPLES PER MONTH
2500 and under	2
2500 to 10,000	7
10,000 to 25,000	25
25,000 to 100,000	100
100,000 to 1,100,000	300

U.S. PUBLIC HEALTH STANDARDS - BACTERIOLOGICAL, CHEMICAL, PHYSICAL

The recognized USPHS drinking water standards are therefore listed as follows:

BACTERIOLOGICAL

Of all the standard ten millilitre (10) ml.) portions examined per month in accordance with the specified procedure, not more than ten (10) per cent should show the presence of organisms of the coliform group.

CHEMICAL AND PHYSICAL

	Present USPHS Drinking Water Standard	Recommended USPHS Drinking Water Standard
Turbidity	10 p.p.m.	5 p.p.m.
Colour	20 units	15 units
Taste	Shall not be Objectionable	
Odour	Shall not be Objectionable	

CHEMICAL AND PHYSICAL

	Present USPHS Drinking Water Standard	Recommended USPHS Drinking Water Standard
Lead (Pb)	0.1 p.p.m.	0.05p.p.m.
Fluoride (inorganic)	1.5 "	Not decided
Arsenic (As)	0.05 "	0.01 p.p.m.
Selenium (Se)	0.05 "	0.01 "
Chromium (Hexavalent)	0.05 "	0.05 "
Copper (Cu)	3.0 "	1.0 "
Iron (Fe)	0.3 "	0.3 "
Zinc (Zn)	15 "	5 "
Chloride (Cl)	250 "	250 "
Sulphate (SO_4)	250 "	250 "
Phenol	0.001 "	0.001 "
Total Solids	500 "	500 "

NEW SUBSTANCES

Detergents		0.5 p.p.m.(ABS)
	Alkyl benzine sulfonate(ABS) is principal agent of most detergents.	
Cadmium (Cd)		0.1 p.p.m.
Cyanide (HCN)		0.2 "
Nitrates (N)		10 "

Standards for the radiological quality of water and the limits for organic phosphate and chlorinated hydrocarbon pesticides are under consideration at the present time and it is expected that

they will be available at an early date. One of the difficulties in establishing such standards is the need for higher chemical training required in their determination. There is the possibility that supervision may have to be provided by government agencies with the exception of the larger plants that may have highly trained personnel available.

TREATMENT REQUIRED TO MAINTAIN STANDARDS

Treatment that assures proper bacteriological quality is chlorination although filtration is a material aid. Ontario has relied on marginal chlorination through the years and has required that the chlorine residual be between 0.2p.p.m. and 0.3p.p.m. after 15 minutes contact between the chlorine and the water. No objection has been raised to the use of super-chlorination or break-point chlorination, wherever an operator of a plant deems it desirable for better operation of his plant. No change is planned in this requirement relative to marginal chlorination at the present time although every consideration is being given and a watchful eye is being kept on the research that goes on relative to the new pollutants that now endangers water supplies.

Many of the chemical constituents that cause unsatisfactory quality are more important in evaluating the quality of ground water from wells than surface waters. Iron, chloride, sulphate and hydrogen sulphide contents often make ground waters objectionable from taste, odour and other standpoints. In some instances, the contents are so high that the water becomes unusable. On the other hand, chemical pollution by industrial wastes of surface

waters has become a greater problem in recent years necessitating that practically all water works systems in industrial areas have to have taste control methods available.

KNOWLEDGE OF POINTS OF CONTAMINATION ENDANGERING WATER SUPPLIES

Proper operation of a water works to meet public health requirements demand that all points of sanitary contamination, which may endanger the potability of the water be known. It should not be assumed that all sewage treatment plants are properly designed, have adequate capacity and are capable of turning out a good effluent on all occasions. In many instances for economic and other factors, the opposite may be the truth and sanitary wastes may be an ever-present danger to the water supply. It is essential therefore, that the location of the points of sanitary discharge in the area be known and the efficiency of the sewage treatments ascertained if one is to take proper steps to safeguard the quality of the water.

Frequent sampling of raw water is desirable at water plants that are endangered by sanitary contamination. Daily sampling is justified in many instances where recognized adverse conditions exist. Super-chlorination, break-point chlorination and other higher degrees of chlorination are needed on occasion to meet the hazards of sanitary contamination from unsatisfactory sewage treatment plants. Therefore, do not take sewage plant effluents for granted. Find out by frequent sampling if they are a danger to the water works and then, if necessary, take every precaution to combat such contamination, until it is eliminated by the provision

of better sewage treatment.

Sources of industrial waste pollution should also be known to the personnel of water works plants. An ever-changing variety of chemical and other waste discharges are reaching water works plants. As a result, it is rare indeed to find a water works in an industrial area which does not have some type of taste control treatment available. Radiological, anionic detergent, pesticide, phenolic and other organic wastes from industrial sources and from land run-off have brought new and perplexing problems that are often difficult to solve. Industries are sometimes located in too close proximity to water works intakes with little regard for the problems that will be created thereby increasing need for careful and close supervision in the water works plant.

In recent years there have appeared in the press and elsewhere statements relative to the increasing hazards to the quality of water supplies from sanitary, chemical and other contaminants that reach and may pass through water works plants. In particular, the number of new enteric viruses that have been discovered to be present in human wastes and against which the usual chlorination treatment has little effect, has caused some concern. It is recognized that modern water treatment methods can and do prevent contaminated water from affecting a community's health in almost every instance. However, there is a limit to even the efficiency of our purification plants if the contaminants are to continue in an ever-changing variety. It is true that conditions are probably not as bad as pictured as there has been no evidence of any major recession to the waterborne

epidemics of a few years ago. It would be folly not follow with every interest the work that is being carried out in this field-the contamination of water supplies by new and old pollutants-and be ready to make changes in water treatment, particularly in the field of chlorination, if changing conditions indicate that such a step is necessary.

RECORDS OF METHODS USED TO SOLVE PROBLEMS ARE ESSENTIAL

Water Works personnel should study and keep accurate records of all adverse conditions that materialize at their plants from year to year. Tastes and odours created by industrial wastes or algae, suspended matter that affects chlorination and filtration, changing chlorine demands, operation in winter months, peak periods, and operation in emergencies such as floods are some of the problems that must be met from time to time. In every instance, water works personnel will eventually find solutions to the condition of the moment. It is an invaluable aid to the solving of problems in the future that a record be kept of the methods that were used to combat conditions such as turbidity, taste and odour formation, frazil ice, algae and chemical contamination that cause concern from time to time.

EMPLOYEE TRAINING FOR WATER WORKS

A well trained operator is definitely of value if a water works plant is to function properly. However, any conclusion that all uncertified operators are unqualified to operate a treatment plant is unjustified. Many operators through adequate initial instruction

from their fellow operators and by studying the literature become well qualified to operate their own or similar plants. It is, of course, an advantage if the instruction that he has acquired in this way can be supplemented by schools of training to enable him to have a better knowledge of the field of water plant operation.

The water treatment plant operator is vital to the health of the community as producer of safe, palatable water, and to the safety of the community as the provider of adequate water to fight fires. It is essential, therefore, that he have every opportunity to provide the personal supervision that is required in this field. There has been a trend in recent years to make water treatment plants automatic so that only a small number of employees will be needed. It is true that a certain amount of automation is helpful in the control of any water works system, but ever-changing characteristics of water requires a personal supervision that cannot be replaced by automatic devices. In smaller communities, there is a tendency to provide part time operation with the operator being used for other duties as well. In some instances, automatic control of the pumping is provided; in other, the plant operates for periods with no supervision or control. If treatment is required in such plants, it cannot be provided properly and accurately at all times without personal supervision. Automatic devices can adjust to the changing demand of the water but they cannot adjust for its changing quality.

It is therefore recognized that an operator is and will continue

to be the main cog in the provision of a satisfactory water from a public health standpoint. It is essential, therefore, that he have assistance and training to assist him to a better understanding of the complex nature of water treatment. As the industrial era develops more fully, there is now a more urgent demand for more research in individual water utilities. There continues to be the need for a centralized research control that would help operators in solving their individual problems. There also should be an appreciation of the importance of the work of operators so that in the future better salaries will help to ensure more interest in the field and a desire on the part of operators for more knowledge to operate their plants.

NEED FOR PROPERLY DESIGNED PLANTS

It is equally important that water works personnel have the tools to do their work properly if they are to provide supervision that is required. In many municipalities, due to economic factors, the design of water works plants is cheapened so that necessary facilities to meet each condition is not available. Yet, the general public expect water works personnel to turn out a good safe product at all times. It is true that in practically every case, that water works personnel give careful, responsible, supervision under the conditions that exist at their individual plants.

Many plants rely on chlorination treatment alone to assure the safety of the water. It is rare that such a plant does not eventually have problems that cannot be adequately met. The water works

personnel can only take every precaution to make sure that chlorination is carried out properly. If marginal chlorination is being used, it is always good practice in such plants to maintain the highest residual that is demanded by the government supervising agencies. If taste control methods are required, the methods that may be used effectively at such plants is limited. In several instances, chlorination is introduced at the high lift pumps prior to the discharge of the water to the distribution system. Control is naturally difficult under such circumstances. One cannot place the blame on operators in every instance if the treatment is not totally adequate. The plant itself is inadequate for proper treatment.

There is also a wide variation in the raw water conditioning that is provided at filtration plants ranging from practically none at all to the full amount of pretreatment. Operators must, therefore, be able to evaluate their plants and the problems that must be met in order to use it to the best of their ability. It must be remembered that plants are designed to a certain criteria and they should be operated on that basis. The trend toward high rate filtration in the industry has been noted but that treatment requires special raw water conditioning, hydraulic design and filter medium to be carried out properly. It is true that a certain amount of overleading can take place, but it is better to operate the filter plant on the basis of the design called for by the consulting engineer.

Research can be of considerable aid to water works personnel

either in conjunction with the government agencies or alone. It permits a better understanding of the capabilities of the plant under every condition and the possibilities for changing the treatment to meet differences in water quality. The responsible water works operator therefore learns to evaluate his plant and to carry out experiments that will enable him to use the facilities to their best advantage.

SUMMARY

The major public health requirements in the operation of water treatment have been listed as follows:

(a) Maintain the quality of the water to meet the standards established by public health and water works authorities.

(b) Know the sources of contamination that endangers the operation of water works plant and be ready to meet the condition that is created by such pollution. In particular, do not assume that discharges from sewage treatment plants in the area are satisfactory.

(c) Water works personnel should secure as much training as possible in order to be able to supervise operation to the best of their ability.

(d) Water works personnel should evaluate the capabilities of their plant and carry out regular research so as to operate it to its peak efficiency.

GROUND WATER SUPPLIES

by

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An Address To
The Ontario Water Resources Commission
Basic Water Works Course
Toronto, Ontario
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GROUND WATER SUPPLIES

A. K. Watt

Supervisor - Ground Water Division - OWRC

Ground water is an important source of water supply throughout the world. Its use in irrigation, industries, municipalities, and rural homes continues to increase. Approximately 30 percent of the total water used in Ontario is ground water. However, because we cannot see it under normal conditions, we often assume that it is present in limited quantities and is really not a satisfactory water supply. It is worthwhile to occasionally review what is known about its source and occurrence and what steps can be taken to increase our knowledge of this very important natural resource.

SOURCE

Ground water is part of the earth's circulatory system known as the hydrologic cycle which is shown diagrammatically in Figure 1. Beginning with moisture-laden air moving over the land masses from the ocean, the next part of the cycle is the precipitation of part of the moisture in the form of rain, hail or snow.

Some of the precipitation is returned to the air through evaporation from the vegetation, ground and inland water surface, while some is transpired to the atmosphere from the plants which have drawn the water up from the soil through the roots. The rest of the precipitation either infiltrates the soil particles to a greater depth than the root zone or runs off directly to streams, lakes and finally the ocean.

The water that infiltrates the soil particles will finally reach a zone where all pore spaces and rock crevices or solution channels are filled with water. The water in this zone of saturation is called ground water.

Studies have shown that in North America the average annual precipitation is about 30 inches. Of this amount approximately 21 inches are returned to the atmosphere through the processes of evaporation and transpiration. Nine inches are returned to the ocean by rivers.

Most of this river water had at one time been ground water. The ground water is seldom stationary but flows slowly under the influence of gravity. Ground water tends to reappear sooner or later at the surface, either in stream channels or along the margins of the continent in the ocean. This fact is readily recognized when we observe rivers and streams continuing to flow after long periods of no rainfall. The rivers are being fed by ground water which drains slowly into the river channels, throughout the drainage system. Only during the more intense or long rainfall periods do appreciable quantities of precipitation run off directly to streams without passing through the ground. It is very important to keep in mimd that ground water and surface water are not separate and distinct but closely interrelated.

STORAGE AND MOVEMENT

The proportion of the nine inches referred to above which is available for use as ground water will depend on geological conditions in that area. Where sand and gravel deposits are

present at the surface of the ground or where bedrock formation with their weathered surfaces outcrop with no overburden above them a maximum amount of infiltration will take place. However, many parts of Ontario have clay or clay-till surface deposits which, while absorbing considerable moisture, particularly at the beginning of a rain, will contribute to a greater amount of surface run off.

As mentioned earlier the ground water is stored in the pore spaces between the sand and clay particles and in the crevices and solution channels of the rock formations. Poorly sorted sand, gravel, silt and clay materials such as occur in till, a glacial deposit, where large and small particles of soil are mixed together, have a smaller proportion of pore space in which water can be stored than in well-sorted materials where all the grain sizes are equal. Figure 2 shows several types of rock interstices and the relationship of rock texture to porosity.

A general range in porosity of natural sediments and sedimentary rocks is given in Table 1.

TABLE 1

Materials	Porosity per cent
Sandstone	4 - 30
Sand, clean and uniform	30 - 40+
Gravel, clean and uniform	30 - 40+
Sand and gravel mixed	15 - 25
Silt and clay - as deposited	40 - 90
Compacted and dewatered	20 - 40
Shale	1 - 35
Limestone	1 - 50

A rock formation may contain many pore spaces which contain a great deal of water but if the pores are small or not connected so water can flow freely from one pore to another the rock may yield only a small amount of water. This introduces the second very important factor used in determining how a rock will act as a source of water. It is called permeability - the ability of a formation to transmit water. A formation such as sand and gravel or creviced limestone which has many pore spaces which are sufficiently large and interconnected to allow ground water to move freely through them is called an aquifer. The amount of ground-water movement varies from about 5 feet a day to 5 feet a year.

Most of us know very little of the amount of water stored in these aquifers or ground-water reservoirs. The OWRC and government agencies in several other provinces, notably Alberta and Saskatchewan, are stepping up their collection of basic data and making an inventory of ground water conditions by means of geological and hydrological surveys. Some idea of the amount of water in storage may be obtained from a statement contained in the U. S. Department of Agriculture Year Book in 1955, --- "The ground water reservoirs of the United States contain far more fresh water than the capacity of all the nation's reservoirs and lakes, including the Great Lakes. It has been estimated that the total usable ground water in storage is of the order of 10 years' precipitation or 30 years' runoff."

WATER-BEARING PROPERTIES OF ROCK FORMATIONS

The Precambrian granites and other intrusive, sedimentary and volcanic rocks underlie 60 percent of the area of the province,

chiefly in northern Ontario. As a rule, these formations are classified as poor aquifers. Wells may obtain sufficient water for the average domestic needs from joint cracks or fracture planes near the surface of these rocks but high capacity wells are confined almost entirely to the sand and gravel deposits in the overburden above them.

The limestones and dolomites of southern Ontario vary widely in their water-yielding properties. They make much better aquifers in the southwestern parts of the province than they do in south-central or eastern Ontario. The quality of the water is generally very hard and is often highly mineralized with sulphur compounds, particularly in the areas closest to Lakes Erie and Ontario and the St. Lawrence River.

The shale formations yield only small quantities of water but the water is much softer than that from the limestone rocks. Salty water is frequently encountered at shallow penetrations of the shale formations.

A wide variety of overburden conditions is present in Ontario. Although much of the area is covered on the surface of the ground with clay or till materials, numerous deposits of sand and gravel are present on top of or within the overburden to provide in most places suitable aquifers for average domestic needs. Areas where high capacity wells for municipal, industrial or irrigational purposes are necessarily more restricted.

EXTRACTION OF GROUND WATER

Aside from the utilization of naturally occurring springs, ground water is recovered by means of wells. Although there are more dug wells in use to-day, probably, than any other type, the number of drilled, driven or bored wells is increasing as a result of improved methods of well construction and the need for deeper wells which provide a more dependable supply of water.

An exhibit has been prepared which illustrates the possible locations of different types of wells. The dug and driven types of wells can be least satisfactory because they are usually the shallowest and are most easily affected by variations in ground-water levels. The drilled well ending in sand and gravel is sometimes developed with an artificial gravel pack to reduce the velocity of water flow into the well. This helps to keep the water free from sand and silt and the screen from materials precipitating out of solution. The rock well requires no screen and, therefore, usually requires less maintenance and rehabilitation. The flowing well is not an indication that the well is good but that the well head is lower than the pressure head of the water in the aquifer at that point.

When water is pumped out of a well the lowering of water pressure at the well site causes water in the aquifer to flow towards it. It is, therefore, only natural that there will be a lowering of water level or water pressure in the vicinity of any pumped well. This lowering forms a cone of depression which varies in size according to the rate at which the well is pumped

and the permeability of the aquifer. The cone of depression in a water table aquifer, one that is not confined, will actually cause a dewatering of the aquifer itself and will spread very slowly. In a confined aquifer which is the situation occurring in many, if not most, of our municipal, drilled wells, the cone of depression is an imaginary pressure surface that spreads out rapidly. In the confined or artesian aquifer the effect of pumping can be observed several hundred or thousand feet away in a few minutes.

Figure 3 shows the affect of a pumped well on the water levels in adjacent wells under water table and artesian conditions.

PUMPING TEST

When a well is constructed, a pumping test should be run to determine the permeability and storage coefficients of the aquifer. These coefficients tell us how fast the aquifer allows the water to move through it and how much water stored in the pores and crevices of the saturated formation is available for use. On the basis of the information obtained from a pumping test it should be possible to give a fairly accurate rating as to the capacity of the well. In such tests, many readings should be taken of water levels in the pumped well and preferably one or more gauge holes, particularly during the early part of the pumping test.

After a well has been put in use the following observations should be made as regularly as possible:

(1) Daily quantity pumped
(2) Daily pumping level
(3) Daily discharge pressure
(4) Weekly static level

If production from a well drops off and the static level remains about the same the trouble could be due to a faulty pump or plugging of the well. In case of pump trouble an experienced pump mechanic should be consulted. If it appears that the well is being gradually plugged with iron or lime scale or with silt and sand particles, some form of chemical or mechanical treatment will be required to rehabilitate the well. Well problems and well maintenance could be the subject of a lecture by itself. We will not take time to discuss them further to-day.

GROUND WATER RECHARGE

If the static level is gradually lowering in a well, it indicates that more water is being removed from the aquifer than is entering by natural recharge. It was mentioned earlier that about 9 inches of water is available annually from precipitation for use in our streams and ground water. This amounts to about 130,000,000 gallons on each square mile of land surface. If we assume at least one half of this amount infiltrates the ground to an aquifer we will have a better understanding of where the recharge will come from that replaces the water removed by pumping.

The lowering of ground water levels in the vicinity of pumped wells is not necessarily something to be alarmed at providing the ever widening cone of depression finally includes sufficient recharge to balance the withdrawals.

Just as in a surface reservoir, it is perfectly feasible to draw on stored water during periods of drought, with a consequent lowering of the water table, just as similar drawing on storage would lower the level of a lake or surface reservoir. The falling water tables we hear about are not unexpected during periods of low recharge and during wet years the storage tends to be replenished.

However, water levels that continue to lower indicate the mining of ground water. The continuation of such overdraft will either lower the water level to the limit of economic lift or will exhaust the stored water.

It should be pointed out here that many aquifers can be recharged by artificial means either in pits similar to those in use at Aylmer, London and Trenton or by means of wells which have been used at Aylmer, Dresden and Forest.

The hydraulics of ground water is a very important study which increases our knowledge of the relationship of ground water supplies to their extraction through wells. It might be the subject of a lecture for a more advanced course.

WATER QUALITY

In moving through the atmosphere and the soil particles, water comes in contact with many soluble materials. These form chemical compounds, or salts, which are contained in solution.

Some rocks are more soluble than others. Granites and other igneous rocks are relatively insoluble but limestones, gypsum and dolomite can be quite soluble. Over long periods of time, considerable amounts of calcium carbonate or sulphate are taken into solution from these rocks.

The hardness of water is due to the presence of bicarbonate and carbonate salts of calcium and magnesium and the alkaline-earth sulphates, chlorides, etc. The former contribute to the "carbonate" or "temporary" hardness and the latter to the "non carbonate" or "permanent" hardness.

Ground water is usually very hard. A hardness scale in common use is as follows:

	Hardness
Soft water	0 -60 p.p.m. or Ca CO_3
Medium or moderate hard water	61 -120 " " " "
Hard water	121 -180 " " " "
Very hard water	greater than 180 " "

WATER USE

The principal uses of ground water are for municipal, industrial and irrigation purposes. The use of ground water has increased in recent years in Ontario particularly in parts of southwestern Ontario. This has contributed to problems of water rights in common with surface water supplies. Irrigation use is to a large degree consumptive use in that the water is lost by evaporation and transpiration and does not return to the aquifer.

Industrial use of water has also increased but its effect on water supply is not as pronounced as most of it is returned to either surface or ground water sources again. Re-use of ground water is practised to a greater degree in some other countries than in Canada.

Approximately 30 percent of the people in Ontario use ground water. If we were to consider only those served by municipal water works systems this percentage is reduced to about 17. In 1958, 164 communities, out of a total of 409, were served entirely by ground water. A comparison of ground water use with other sources of supply is shown in Table 2.

Seventy-seven percent of the well supplies were untreated, 20 percent required chlorination only and 3 percent had iron removal, aeration or softening with or without chlorination.

CONCLUSION

In conclusion, we may say that ground water supplies in Ontario are very important to its economy. Although tremendous quantities are unused, we do not know exactly what these reserves amount to. Ground water investigations will have to be greatly increased before this information is known.

Ground water is a renewable resource. Within limits of local precipitation and geological conditions, ground water reservoirs can be lowered annually without endangering the supply provided the withdrawals are equal to the average perennial recharge.

Finally, although ground water is usually very hard and may contain other undesirable chemical constituents, the advantages of cool and constant temperatures along with the economy of setting up and operating the water works system usually make it the preferred source of supply if the desired quantity of water is assured.

SURFACE WATER SUPPLIES

by

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An Address To
The Ontario Water Resources Commission
Basic Water Works Course
Toronto, Ontario
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SURFACE WATER SUPPLIES

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SURFACE WATER SUPPLIES

This general lecture on surface water supplies is directed initially to water supply in its broad sense, and then to municipal water supply. Presented are background information on hydrology and Ontario water resources and a review of factors pertaining to surface water quality and intake works.

SURFACE WATER

First of all, what is surface water? It is the water in that phase of the hydrologic cycle in which it appears in liquid form on the surface of the earth. It includes both fresh and salt water, water in streams, lakes, ponds, canals, bays and oceans. While the prime source of surface water is precipitation, water that has seeped out of the ground or issued from springs is also included in this category. So is water moving through man-made conduits, even though these are underground. An additional classification is "diffused water", which is rainfall that has not yet infiltrated into the ground or drained into a defined watercourse to become "runoff".

USES AND CONSUMPTION

There is no need to remind this group of man's dependance on water and how the availability of water is directly related to welfare and standard of living of the people. Not only is water essential to man for his biological existence but it is an integral

part of his social, economic and cultural development.

Man's use of water increases continually with respect to both volume and function. In addition to domestic use, the waters of the earth serve man through navigation, power development, recreation, irrigation, industrial processing and wastewater removal, and are essential to maintain livestock, and terrestial and equatic plants and animals.

An average person of moderate activity requires 3 to 5 pints of water per day. Some of this may be derived from foods. The water used in an ancient village has been reported as 3 to 5 gallons per capita per day. Today, in a home without a pressure water system, about 10 gallons of water per capita per day is drawn. These figures are cited for comparison with present day use in villages and cities. In a village with negligible industrial development, the normal range is 40 to 60 g.p.c.d. In cities where higher values reflect industrial development the range is 100 to 200 g.p.c.d.

TABLE 1

Examples of Municipal Water Consumption

Metropolitan Toronto Municipalities

1955

	Total Consumption		Industrial	Domestic	
	M.G.D.	G.P.C.D.		M.G.D.	G.P.C.D.
Toronto	103.04	151.1	70.66	32.38	47.5
York	7.43	65.6	1.87	5.56	49.0
New Toronto	5.36	476.0	4.70	0.66	58.8
East York	3.78	54.6	0.63	3.15	45.4
Leaside	2.55	151.0	1.88	0.67	39.7
Forest Hill	1.47	77.0	0.01	1.46	76.4
Weston	1.12	122.5	0.55	0.57	62.3
Mimico	0.78	59.8	0.10	0.68	52.1
Long Branch	0.59	61.3	0.14	0.45	46.7
Swansea	0.53	62.1	0.11	0.42	49.3
Etobicoke	6.67	71.0	1.60	5.07	54.1
North York	8.24	55.5	1.33	6.91	46.6
Scarboro					
TOTAL	148.12	114.0	85.63	62.49	48.0

Table 1 shows the total, industrial and domestic water consumption for the year 1955 for the municipalities in Metropolitan Toronto. It will be noted that the rate of domestic consumption varies from 39.7 to 76.4 g.p.c.d. with an average of 48.0. The total rate which reflects industrial use varies from 54.6 to 476.0 with an average of 114.0 g.p.c.d. It has been predicted that this figure will increase to 137 by 1980. For American communities, the United States Public Health Service predicts a consumption rate of 153 imperial gallons per capita per day by 1980.

Municipal water consumption is actually small in relation to the amount of water privately pumped and used by industry and the amount used for hydro or thermal power development. Table 2 shows water use and discharge figures for comparison purposes.

TABLE 2

Examples of Miscellaneous Water Uses

Use & Discharge	Rate
Theoretical Water Requirement of all of Ontario's present population (6,000,000 @ 150 g.p.c.d.)	1,700 c.f.s.
Mean Annual Flow in Niagara River	195,800 c.f.s.
Mean Annual Flow in Grand River	2,000 c.f.s.
Cooling Water requirement for New Lakeview Thermal Generating station of H.E.P.C.	3,000 c.f.s.
DeCew Falls Hydro Generating Station of H.E.P.C.	6,000 ± c.f.s.
Pulp and Paper Mill or Steel Mill	100
1000 ton/day capacity	

From these few examples the relative position of municipal water requirements is apparent.

Terms applied to a significant classification of water use are consumptive and non-consumptive. A consumptive use is one which removes water from an available form. Such a use is irrigation where water is lost to the atmosphere by evaporation and transpiration. Municipal, industrial and power development uses are non-consumptive because the water remains available

although its quality may have been altered.

HYDROLOGY

What do we know about our overall water supply, - our water resources? The science concerned with the occurrence, circulation and distribution of water in the atmosphere, on the surface of the ground and underground is called hydrology. It is closely related in many phases to meteorology and geology. These are sciences concerned with weather and the earth's structure respectively.

The hydrologic cycle is the descriptive term applied to the general circulation of water from the seas to the atmosphere, to the ground and back to the seas or atmosphere again. In the various stages, water may have a liquid, solid or gaseous form. Starting with the ocean, evaporation resulting from temperature and vapour pressure differences takes place and water vapour rises into the atmosphere. Condensation occurs with cooling and rain or other forms of precipitation fall back to the lands or seas. Of that portion falling on the land, some is retained temporarily, in the soil, in surface depressions, or on vegetation, to be returned to the atmosphere by evaporation and transpiration. The remainder moves by devious surface and/or underground routes back to the sea. This is an over-simplified description of a process in which all phases of the cycle are occurring simultaneously.

The hydrologic characteristics of an area are determined largely by (1) the climate of the region and (2) the geological structure of the area. Climatic factors are of importance because of their influence on the magnitude and distribution of precipitation and the rate of evaporation. Geological factors influence

surface and sub-surface movement and storage of water.

The earth's supply of water is relatively constant but it is ceaselessly on the move. It is changing in both form and location. The distribution and that portion of water in an available form is what concerns us. Unbalanced distribution may result in floods or droughts.

ONTARIO'S WATER SUPPLY

What is the water resources picture for Ontario? Some seventeen (17) per cent of the area of the Province is covered by water in lakes and rivers.

Total Area*	412,582 square miles
Land Area	349,092 " "
Water Area*	68,490 " "

* Excluding the water areas of Hudson Bay and James Bay.

These surface supplies in conjunction with the ground water supplies, as reviewed by Mr. Watt, are our water resources for they are the supplies available for us to use and otherwise manage with respect to quality and movement.

Precipitation - The origin of our water resources is, as previously noted, precipitation. Over Southern Ontario the mean annual precipitations range from 25 to 40 inches with a corresponding range of 15 to 40 inches over the north. If we take an average as 30 inches and assumed that it falls at one time, it would mean that water would cover the entire province to a depth of 2½ feet. Fortunately, the monthly rate of precipitation is

reasonably uniform.

The Meteorological Branch of the Department of Transport - Canada, is the co-ordinating organization in the recording and reporting of climatic conditions. Long term records are available for many locations and the number of stations is constantly increasing. Some 350 stations in Ontario are reported in their bulletin Monthly Weather Map.

Drainage Basins - The run-off resulting from precipitation in Ontario drains either to the Atlantic Ocean through the Great Lakes - St. Lawrence System or to James Bay or Hudson Bay through such main rivers as the Moose, Albany, Severn and Nelson. The drainage divide runs east and west about 50 miles north of Lake Superior. The area of provincial lands draining northward is about 2½ times that tributory to the St. Lawrence system.

The Great Lakes - St. Lawrence System is a natural resource of major importance. This is emphasized by the fact that more than 97 per cent of the 6 million people in Ontario live in this drainage basin and over 90 per cent reside within 50 miles of its shores. The area of the drainage basin above Cornwall is close to 300,000 square miles of which 40 per cent lies in Ontario. The Ottawa River has an additional contributing drainage basin area of 56,000 square miles in Ontario and Quebec.

Some facts concerning the Great Lakes are shown in Table 3.

TABLE 3

PERTINENT INFORMATION ON THE GREAT LAKES

Lakes	Length Miles	Width Miles	Area of Water Surface Sq. Miles	Area on Canadian Side of Boundary Sq. Miles	Area of Drainage Basin Sq. Miles	Maximum Recorded Depth Sq. Miles	Elevation above Sea-Level Feet
Superior...	383	160	31,820	11,200	80,700	1,302	602.2
Michigan*..	321	118	22,400		69,040	923	580.8
Huron......	247	101	23,010	13,675	72,600	750	580.8
St. Clair..	26	24	460	270	6,420	23	575.3
Erie.......	241	57	9,940	5,094	34,690	210	572.4
Ontario	193	53	7,540	3,727	34,640	774	245.9
			95,170	33,966	298,090		

* Although Lake Michigan does not form part of Ontario's boundary, it has been included because it is one of the Great Lakes.

Hydrometric Records - Table 4 gives examples of the average, maximum and minimum discharges from some rivers in Ontario.

TABLE 4

Discharge from some Ontario Rivers

River	Location	Drainage Area Sq.Miles	Average	Maximum	Minimum
St. Lawrence	Iroquois	298,160	240,900	315,000	139,000
Ottawa	Grenville	55,560	67,000	287,000	23,270
French	French R.Sta.	5,370	6,120	20,500	1,040
Trent	Heeley Falls	3,514	3,070	17,360	166
Grand	Brantford	2,010	1,930	47,800	65
Credit	Erindale	320	275	11,200	3

The Water Resources Branch of the Department of Northern Affairs and National Resources co-ordinates the recording and reporting of hydrometric information. The data in Table 4 are taken from their recent publication, Water Resources Paper No. 119 which covers the St. Lawrence and Southern Hudson Bay Drainage Areas for the climatic years 1955-56 and 1956-57. Of the 282 stations reported in Ontario, 262 show discharge data and the remainder water level data. Many organizations assist in providing the information reported.

The Canadian Hydrographic Service of the Department of Mines and Technical Surveys records and reports the precise water levels in the Great Lakes. They also publish navigation charts with water depths which are a useful reference for initial intake studies.

From the above discussions on precipitation, water areas and stream discharges, it is apparent that our overall water resources

are ample. Problems of quantity are related to distribution and discharge control.

SURFACE WATER QUALITY

The quality of surface water varies widely from stream to river to lake, from basin to basin and with time at the same location. Some factors influencing quality are natural, others artificial. Small spring fed upland streams normally yield a clear palatable water. Rain storms may cause an increase in solids and turbidity. Any bacteria present are usually of insignificant origin. Larger streams usually drain inhabited areas and are subject to more serious types of pollution. Wastewater of a sanitary or industrial nature may be modifying the original water quality. The quality of water from lakes, ponds and artificial reservoirs may be somewhat better because of the effect of natural sedimentation. Here, care must be taken to avoid pollution from local sources which are usually near the shore. Prime examples of good lake sources are the Great Lakes.

The qualities important to municipal water supply can be classed as biological, physical, chemical and those related to radioactivity. Mr. Galimbert has discussed water quality in relation to public health. Further consideration of quality in terms of the surface water source is pertinent.

A sanitary survey of the potential supply should always be conducted and quality related to current studies.

Biological Quality. Biological quality includes bacterial quality and factors related to plankton and equatic vegetation.

For obvious reasons, water of the best bacterial quality should be sought. In rivers, the intake should be upstream from the area of development. In lakes, the intake should be located and extended to avoid the normal paths of polluted waters. These comments apply equally for other quality aspects.

Standards are sometimes used to relate raw water quality and treatment. An example of such a standard is provided below.

	Treatment Required		Raw Water Coliform Count per 100 ml
1.	Chlorination only	-	up to 50
2.	Pre-chlorination, coagulation, sedimentation and filtration	-	3500
3.	Coagulation, sedimentation, filtration and post-chlorination	-	5000
4.	Pre-chlorination, coagulation, sedimentation, filtration and post-chlorination	-	20,000*
5.	As 4 with double stage sedimentation	-	50,000

* The upper limit tends to be increasing.

Chlorination and efficient coagulation, sedimentation and filtration in a modern type of filtration plant are becoming increasingly important as our population grows. Virus removal or inactivation is dependent on complete treatment. Every surface water supply requires chlorination as minimum treatment.

Plankton may have a pronounced influence in the suitability of water for a municipal source and on the cost of treatment. Many of you have experienced problems associated with algae. The same is true for aquatic vegetation. Aspects of these qualities will be

reviewed in later lectures.

Physical Quality - Of common concern are the physical qualities of temperature, appearance (colour and turbidity) and taste and odour.

Temperature is important to the palatability of the water and to some industrial uses. Cool or cold water is desirable. In a turbulent stream, little choice is available. In lakes, the deeper intake generally produces cooler waters. The minimum water temperature is usually just above the freezing point at 32°F. The upper values range with source; Lake Superior - 60°F; Lake Ontario - 70°F; Lake Erie - up to 80°F. Streams, except for spring fed creeks usually rise to the 70°-80° range.

Colour may result from a number of natural or artificial causes. The waters of northern Ontario have a distinct brown hue that requires effective coagulation for removal. This colour is often related to marsh sources. Iron is sometimes responsible for colour. Some industrial wastes are highly coloured.

Turbidity is the term applied to describe the presence of substances in water which interfere with its clarity. It is most frequently associated with soil solids being carried in the water. The upflow type of clarifier has application where moderate to high levels of turbidity are experienced. The average annual turbidity levels for most waters drawn from Lake Ontario are below 10 p.p.m. At the R.C. Harris (Toronto) plant, the annual averages range from 2.2 to 7.3. Extreme levels are recorded during flood periods. After Hurricane Hazel, the turbidity along Lake Ontario exceeded 3000 p.p.m. at some intakes.

Chemical Qualities - Some chemical qualities are of significance. Hardness, iron, chlorides, sulphides, phenol, pH, acidity, alkalinity and fluorides are qualities usually checked. Further analysis for a variety of inorganic, organic and toxic compounds may be indicated from a study of local conditions. Some of these qualities are related to health, others to taste, appearance, treatment or use. The results of determinations for dissolved oxygen, biochemical oxygen demand and components of the nitrogen cycle are useful in assessing the sanitary quality of the water.

Chlorides, sulphides and phenol may be taste factors. A measure of the corrosive property of water is provided by pH. Alkalinity is necessary for an efficient coagulation reaction. Fluorides are related to dental carries. Hardness is important to domestic and industrial uses.

These characteristics may fluctuate little or widely throughout the year. Hardness in the Great Lakes increases to a maximum of about 125 p.p.m. in Lake Ontario and decreases as the softer water (55 p.p.m.) of the Ottawa River is received. The waters of the Trent River vary between 90-100 p.p.m. while those of the Grand range from 130 to 350 p.p.m. The lower figure represents quality during flood flow and the upper figure during low fall flow when the ground water contribution predominates.

The pH values of surface waters are usually above 7. An exception is the water in the Sudbury area where values as low as 4 are recorded. These are due to the leeching of sulphur compounds from local rocks.

Radioactivity - With rapid development in the nuclear field and with increasing research, power and industrial applications, this phase of quality is most significant. Standards are being suggested and adopted but much remains to be learned.

Quality Protection - In Ontario, the Ontario Water Resources Commission is vested with wide authority to protect the quality of our natural waters. Objectives for water quality have been adopted in terms of both effluent and stream. A synopsis of these objectives is appended to these notes. The intent is to avoid impairment of the waters for further beneficial use. Section 27 of The Ontario Water Resources Commission Act deals with the discharge of contaminating materials to a watercourse.

In accordance with section 28, an area surrounding a source of public water supply can be defined and prescribed for specific pollution protection. Little use is made of this section because of the protection provided through Section 27 and the provisions of the Public Health Act.

The International Joint Commission is active in matters of pollution related to the boundary waters between Canada and the United States.

SELECTION OF SOURCE

Sources of surface water for a municipal supply are lakes, reservoirs, rivers, streams and ponds. Four main parameters are applied to the selection of a source and a particular intake site. These are quality, quantity, reliability and cost.

Quality - Raw water quality is of prime importance. The more important factors have already been discussed. Most waters can be made safe and tolerable by application of a combination of treatment processes. Costs, however, may rise excessively.

A sanitary survey of the area should be conducted, which would include quality sampling, outfall examination and current studies. From this the possibility of obtaining a satisfactory water can be determined and a site or sites selected for further investigation.

Quantity - The adequacy of the supply must be definite. For rivers and streams this should be based on flow measurements whenever possible. Where discharge records are not available, hydrological studies based on precipitation record may be applied. Drought and flood conditions must be considered. Artificial impounding may be required to ensure an adequate supply.

For large lakes, the visible volume of water may indicate their adequacy. For smaller lakes, a detailed hydrological study is warranted. Maximum and minimum water levels should be determined.

Reliability - Seldon are intake works duplicated as with pumps, treatment units and feed mains so that source and site must not present undue hazards to continuous operation. Factors for consideration are potential structural damage from waves, floods, ice or ships, and decreased capacity from blockage by ice, silt or other foreign matter.

Cost - The quality of the water should be such that treatment is economical. Intake costs must be assessed against water quality

and treatment costs.

INTAKES

The term intake refers to the portion of a surface water supply system that conveys the water from the source to the water purification plant or pumping station. It includes the actual inlet structure and the connecting conduit.

The intake is an expensive item and cannot be readily altered, enlarged or re-located. Therefore, careful planning with respect to location, capacity and construction is needed. The location may be determined by existing facilities, by economics or physical conditions. Capacity is normally provided well beyond immediate needs and in relation to projected growth. The geological conditions of the site must be related to the stability of the works and construction methods.

INLET STRUCTURES

Early inlet structures were frequently elbows supported by a rock-filled crib arranged to draw water at some height above the lake bottom. High entrance velocity encouraged ice, sticks, fish etc. to be drawn into the intake. Where screens were provided these proved troublesome.

Through experience improved designs have been developed. The elbow has been replaced or supplemented by an expanding bell mouth. Spaced above this opening, a cover plate is placed so that water enters horizontally around a cylinder of large area. A low inlet velocity is obtained in the range of 6 inches per second. Vertical currents and vortices are avoided. The

materials used may be cast iron, steel or concrete or a combination of these.

The importance of keeping the opening some distance above the lake bottom was recently confirmed at a Lake Erie intake where a construction error occurred and silting of the conduit resulted.

Tower intake has been employed. The inlet structure rises to and above the water level. Ports and gates are provided so that the level from which water is drawn can be selected.

The bellmouth intake with the horizontal top plate may be suitable for a deep river but in smaller rivers a different type of structure is used. The plane of the opening is placed vertically in the line of current. Again a cone is used to reduce entrance velocity. In special instances the inlet may be a port in a wall, dam or other structure.

Coarse bar screens may be provided at the inlet but screening should be provided at the shore end of the intake works.

INTAKE CONDUIT

Cast iron pipe is commonly used for small intakes. Plastic has also been employed. Steel pipe is common for larger sizes. Some protection against corrosion such as wrapping or coating may be provided. Steel has the advantage over precast concrete pipes of being light. The latter have been used with satisfaction in recent years.

Ease of installation and reliability of joints with some measure of flexibility are important. Installation costs may run \$50.00 to \$60.00 per foot in addition to the cost of the pipe which approximates \$15.00, \$17.00 and \$21.00 per lineal foot for 24, 30 and 36 inch diameter sizes respectively.

Bedding of the pipe is important. The conduit may be laid on the bottom or in a trench. Waves, ice, currents or navigation may dictate the installation. Excavation near shore is usually fairly deep. The trench should be carried out well beyond the point where ice damage would be expected. Tunnels are sometimes employed for sections of an intake.

The conduit should be so graded that any air can pass out of the intake. Generally speaking, the grade is upwards to suction well. If a high point is incorporated into the design, a means should be provided for bleeding off air from this point. Special valves or a separate bleeder line may be used. If this care is not taken the capacity of the intake will be seriously reduced by air binding. Air results from dissolved gasses being released due to temperature increase or pressure reduction.

INTAKE CAPACITY

The capacity of the intake should be calculated for minimum water stage (level) conditions. The friction losses for the inlet, pipe, valves and screen should be considered. Surge at the pump suction well must also be taken into account to avoid flooding of this area when pumps are stopped.

ICE HAZARDS

In cold climates, one of the greatest hazards to intakes is blockage by ice. Ice is classified as: surface, anchor and frazil.

Surface ice is of little physical hazard to the intake structure but may slow down or alter natural purification processes and reduce the quality of the water supply.

Anchor ice forms beneath the water surface on objects which radiate heat rapidly such as valves, gratings and plates. It is usually associated with shallow open water and clear cold nights.

Frazil ice or needle ice consists of submerged networks of ice crystals. It is most susceptible to movement by even slight currents and can readily be carried into an intake. Reversal of flow is sometimes employed and many designs provide for this.

SUMMARY

In Ontario in 1958, of 409 communities with municipal water works systems, 40 per cent have ground water sources and 60 per cent surface water sources. Slightly over 4,000,000 people are served with the respective percentages being 17 and 83.

With the rapid development in Ontario, we will see greater dependence placed on the Great Lakes System as a water source. Some pipe-line developments have been undertaken to serve multiple municipalities and more can be expected.

OBJECTIVES FOR WATER QUALITY CONTROL IN ONTARIO

Adopted by the Ontario Water Resources Commission

These objectives are for all waters in the Province of Ontario, and it is anticipated that in certain specific instances, influenced by local conditions, more stringent requirements may be found necessary.

General Objectives:

All wastes, including sanitary sewage, storm water, and industrial effluents, shall be in such condition when discharged into any receiving waters that they will not create conditions which will adversely affect the use of these waters for the following purposes; source of domestic water supply, navigation, fish and wild life, bathing, recreation, agriculture and other riparian activities.

In general, adverse conditions are caused by:

(a) Excessive bacterial, physical or chemical contamination.

(b) Unnatural deposits in the stream, interfering with navigation, fish and wild life, bathing, recreation or destruction of aesthetic values.

(c) Toxic substances and materials imparting objectionable tastes and odours to waters used for domestic or industrial purposes.

(d) Floating materials, including oils, grease, garbage, sewage solids, or other refuse.

(e) Discharges causing abnormal temperature, colour or other changes.

Specific Objectives:

In more specific terms, adequate controls of pollution will necessitate the following objectives for:

(a) Sanitary Sewage, Storm Water, and Wastes from Water Craft:

Sufficient treatment for adequate removal or reduction of solids, bacteria and chemical constituents which may interfere unreasonably with the use of these waters for the purposes afore-mentioned.

Adequate protection for these waters, except in certain specific instances influenced by local conditions, should be provided if the coliform M.P.N. median value does not exceed 2,400 per 100 Ml. at any point in the waters following initial dilution.

(b) Industrial Wastes:

(1) Chemical Wastes - Phenolic Type

Industrial waste Effluents from phenolic hydro-carbon and other chemical plants will cause objectionable tastes or odours in drinking or industrial water supplies and may taint the flesh of fish.

Adequate protection should be provided for these waters if the concentration of phenol or phenolic equivalents does not exceed an average of 2 P.P.B. and a maximum of 5 P.P.B. at any point in these waters following initial dilution. This quality in the receiving waters will probably be attained if plant effluents are limited to 20 P.P.B. of phenol or phenolic equivalents.

Some of the industries producing phenolic wastes are: coke, synthetic resin, oil refining, petroleum cracking, tar, road oil, creosoting, wood distillation, and dye manufacturing plants.

(2) Chemical Wastes, Other than Phenolic:

Adequate protection should be provided if:

(a) The PH of these waters following initial dilution is not less than 6.7 nor more than 8.5. This quality in the receiving waters will probably be attained if plant effluents are adjusted to a PH value within the range of 5.5 and 10.6.

(b) The iron content of these waters following initial dilution does not exceed 0.3 P. P. M. This quality in the receiving waters will probably be attained if plant effluents are limited to 17 P. P. M. of iron in terms of Fe.

(c) The odor-producing substances in the effluent are reduced to a point that following initial dilution with these waters the mixture does not have a threshold odor number in excess of four due to such added material.

(d) Unnatural color and turbidity of the wastes are reduced to a point that these waters will not be offensive in appearance or otherwise unattractive for the aforementioned uses.

(e) Oil and floating solids are reduced to a point such that they will not create fire hazards, coat hulls of water craft, injure fish or wild life or their habitat, or will adversely affect public or private recreational development or other legitimate shore line developments or uses. Protection should be provided for these waters if plant effluents or storm water discharges from premises do not contain oils, as determined by extraction in excess of 15 P. P. M., or a sufficient amount to create more than a faint irridescence.

Some of the industries producing chemical wastes other than phenolic are: Oil wells and petroleum refineries, gasoline filling stations and bulk stations, styrene co-polymer, synthetic pharmaceutical, synthetic fibre, iron and steel, alkali chemical, rubber fabricating, dye manufacturing, and acid manufacturing plants.

(3) Highly Toxic Wastes:

Adequate protection should be provided for these waters if materials highly toxic to human, fish, aquatic, or wild life are eliminated.

Some of the industries producing highly toxic wastes are: metal plating and finishing plants discharging cyanides, chromium or other toxic wastes; chemical and pharmaceutical plants and coke ovens. Wastes containing toxic concentrations of free halogens and wastes containing resin and fatty acid soaps are included in this category.

(4) Deoxygenating Wastes:

Adequate protection of these waters should result if sufficient treatment is provided for the substantial removal of solids, bacteria, chemical constituents and other substances capable of reducing the dissolved oxygen content of these waters unreasonably. In addition to sewage some of the industries producing these wastes are: tanneries, glue and gelatine plants, alcohol, including breweries and distilleries, wool scouring, textile, pulp and paper, food processing plants such as meat packing and dairy plants, corn products, beet sugar, fish processing and dehydration plants.

LEGAL PROBLEMS IN THE SUPPLY AND TREATMENT OF WATER

by

Henry Landis

Solicitor - Ontario Water Resources Commission

An Address To
The Ontario Water Resources Commission
Basic Water Works Course
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LEGAL PROBLEMS IN THE SUPPLY AND TREATMENT OF WATER

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I will first deal with the authority in the Public Utilities Act, R.S.O. 1960, chap.335, under which municipalities may establish and operate water works and treat the water supplied by such water works. Section 2(1) confers a broad power on municipalities to establish and operate water works and to acquire or expropriate land, waters and water privileges and rights of diversion of lakes or rivers as may be necessary for water works purposes or for protecting the water works or preserving the quality of the water supplied subject to s.2(2) which prohibits the expropriation of any land or water or water privileges which is not situate within 15 miles of the municipality and prohibits the taking of water from any lake or water except within 15 miles of the municipality. In either case the municipality cannot interfere with the water works of any other municipality or the supply of water to such other municipality which is actually being used by the other municipality.

Section 2(3) confers power to purchase existing water works and s.5 confers power to lay down pipes, tanks, reservoirs and other structures for the purpose of distributing the water.

Section 38 provides that the municipality may transfer the control and management of the water works which the municipality owns or operates to a Commission to be called "The Public Utilities Commission of the (particular municipality)" and s.41(1) provides

that where the Commission has been established and has been given the power of control and management, the municipality shall no longer exercise the rights and powers with respect to the water works which it has under the Act and these rights and powers shall be exercised by the Commission. Thus the municipality itself may own and operate the water works or, if it desires, may entrust the control and management of a water works to a Public Utilities Commission of the municipality. Although under s.42(1) the Public Utilities Commission is a corporation separate from the municipal corporation and the Commission manages the water works, in law the Commission is the statutory agent of the municipality and any action for damage caused by the operation of the water works or treatment of the water must be brought against the municipality as well as against the Public Utilities Commission. The Commission would be liable for the negligence of its employees in the treatment or distribution of water on the principle that a master is responsible for the negligence of his servant performed in the scope of his employment. The employee would be personally liable and the municipality would be liable on the ground that the Commission is the statutory agent of the municipality.

Section 12 confers power on a municipal corporation to pass by-laws for regulating the "time, manner, extent and nature of the supply by the works, the building or persons to which and to whom the water shall be furnished, the price to be paid therefor, and every other matter or thing related to or connected therewith that it may be necessary or proper to regulate in order to secure to the inhabitants of the municipality a continued and abundant

supply of pure and wholesome water,.....". Presumably under s.41(1) where a Public Utilities Commission has been established by the municipality, the power to pass by-laws under s.12 can be exercised only by the Public Utilities Commission.

An interesting question which arises is whether the municipality, if it wishes to treat the water supply, must pass a by-law for this purpose under s.12 or whether the municipality, as the owner of the water works, can administratively and not by by-law under s.12, treat the water supply. On the one hand it may be argued that the municipality, as the owner of the water works and the water produced in it, is able to deal with the treatment of the water in the same way that the owner of any property is able to deal with it, and need not pass by-laws for this purpose. On this view, the only limitation on the freedom of the municipality with respect to treatment of the water is the general law of negligence or contract, and so long as the treatment or lack of treatment of the water by the municipality does not involve a breach of contract or harm to users of the water, the municipality is free to treat or not treat the water in any way it pleases. Another and a more reasonable view is that the municipality, if it wishes to treat the water supply, must do so by means of a by-law passed under s.12. If such a by-law were passed, not only would the general law of contract and negligence apply, but the validity of the by-law would be tested by the standard set out in s.12 namely, the purpose of the by-law must be "to secure to the inhabitants of the municipality a continued and abundant supply of pure and wholesome water....". In other words, a municipality must pass a by-law dealing with the treatment processes, such as chlorination or filtration and if this

by-law is not passed, the municipality has no power to treat the water supplied by the water works. Moreover, if a by-law is passed and the purpose of the by-law is not to secure to the inhabitants "a continued and abundant supply of pure and wholesome water", but some other purpose, the by-law is invalid. In support of this latter view, it may be argued that there would be no purpose in having s.12 in the Public Utilities Act if a municipality could regulate the treatment of the water supply without passing a by-law and, therefore, the treatment of the water supply must be by a by-law under s.12. In further support of the latter view it should be pointed out that under s.9 of the Municipal Act, R.S.O. 1960, chap. 249, the powers of the municipal corporation must be exercised by its Council and under s.242(1) of that Act, except where otherwise provided, the powers of a Council must be exercised by by-law.

The importance of these two views is that if the first view were adopted, a municipality could add substances such as fluorine to its water supply without passing a by-law authorizing such an addition, and there would be no statutory restriction on its power to add fluorine such as whether the addition of fluorine is intended to secure to the inhabitants a continued supply of "pure and wholesome water" as provided in s.12. On the other hand, if the second view were adopted, the municipality would, if it wished to add a substance such as fluorine or any other chemical substance to its water supply, need to pass a by-law for this purpose and the power of the municipality to add the substance would be tested by the standard set out in s.12, namely, whether the addition of the substance was intended to secure a supply of "pure and wholesome

water" to the inhabitants. Moreover, no municipality could treat its water supply unless the treatment was specified in a by-law of the municipality, and if such a by-law was not passed, the treatment of the water by chlorination or filtration or any other means would be beyond the power of the municipality under the Public Utilities Act and would be unlawful unless statutory authorization for the treatment is found elsewhere.

The issue of fluoridation of water under a by-law passed under s.43 of the Municipality of Metropolitan Toronto Act, R.S.O. 1960, chap.260, was settled by the Supreme Court of Canada in the case of Municipality of Metropolitan Toronto v. The Corporation of the Village of Forest Hill (1957) S.C.R. 569. Section 43 of the Municipality of Metropolitan Toronto Act is in substantially the same terms as s.12 of the Public Utilities Act so far as the regulation of the supply of water from the water works system of the Municipality of Metropolitan Toronto is concerned. The question before the Court was whether a by-law passed under s.43 and providing for the fluoridation of the municipal water supply was a by-law "to secure....a continued and abundant supply of pure and wholesome water...." within the meaning of those terms in s.43. The majority of the Supreme Court held that the purpose of the by-law was not to furnish water for its accepted purposes only but to use the water as a means of rendering teeth less susceptible to decay, that is as a means of effecting compulsory preventive medication. As Mr. Justice Rand put it at p.572, "But it is not to promote the ordinary use of water as a physical requisite for the body that fluoridation is proposed. The process has a distinct and different purpose; it is not a means to an end

of wholesome water for water's function, but to an end of a special health purpose for which a water supply is made use of as a means." This decision indicates that both under s.12 of the Public Utilities Act and under s.43 of the Municipality of Metropolitan Toronto Act, a by-law dealing with the treatment of water must, in order to be valid, be for the purpose of rendering the water supply suitable or more suitable for the accepted purposes for which water is used, and if the purpose of the by-law is the promotion of health, the by-law will be invalid. Thus, if the by-law required the treatment of water by means of water soluble vitamins or minerals for the promotion of health, the by-law would be invalid.

As a result of this case the Public Health Act was amended in 1957 by The Public Health Amendment Act, 1957, chap.97, s.5 (now R.S.O. 1960, chap.321, s.79), to permit specified municipalities to continue their fluoridation of the municipal water supply. Section 80 of the Public Health Act, R.S.O. 1960, chap.321 provides that the specified municipalities have the power to submit the question of fluoridation to a vote of the electors in the municipality. The section also provides that if a petition signed by 10% or more of the total number of persons appearing on the last revised voters list as qualified to vote requests the municipal council to submit the issue of fluoridation to the electors, the council must submit such question and if a majority vote against fluoridation the municipality shall discontinue the fluoridation system.

Section 55 of the Public Utilities Act provides that where there is a sufficient supply of the public utility, the corporation

shall supply all buildings within the municipality situate upon land lying along the line of any supply pipe, upon written request. In the St. Lawrence Rendering Company Ltd. v. The City of Cornwall (1951) O.R. 669, the City discontinued the supply of water to the plaintiff's plant which was situated along the line of a supply pipe, on the ground that the plaintiff was maintaining a nuisance by emitting noxious gases. The Court held that the City could not discontinue the supply of water to the plaintiff company because s.55 imposed a duty on a municipality operating a public utility for the supply of water to continue such supply to the plaintiff and to any other person in the same position, if the other conditions of s.55 were met. This case should be compared with Seguin v. The Town of Hawkesbury (1955) O.R. 956. In this case the plaintiff's house was destroyed by fire, in spite of the prompt effort of the Town's Fire Department, because the water pressure in the mains was too low to obtain a sufficient supply of water to put out the fire. The low pressure was the result of the Town allowing the fire alarm signal in the pumping station to fall into disrepair, thereby preventing the engineer in charge of the pump from receiving prompt notice of the fire and of the need for an increased water supply. The Court of Appeal held that s. 2 of the Public Utilities Act is permissive, and does not impose a duty on a municipality to provide a water work or to provide a reasonable supply of water under reasonable pressure for the purpose of fire protection. Therefore, if the municipality omits to do something which a reasonable man would do such as repair the fire alarm signal, there is no breach of duty and no liability for negligence. The case implies that there is no common law duty to supply water and this implication appears to conflict with the dictum in the St.

Lawrence case that a municipality operating a public utility for the supply of water is under a duty at common law as well as under s.55 of the Public Utilities Act to supply water. The two cases can be reconciled with respect to the statutory duty aspect since there was no question in the Seguin case of discontinuing a supply of water to a building situate on the line of a supply pipe, which is the basis of the application of s.55 and the decision in the St. Lawrence case.

Section 10 of the Public Utilities Act provides that the municipal or public utilities corporation is not liable for damages caused by the breaking of any service pipe or attachment, or for shutting off of water to repair or to tap mains, if reasonable notice of the intention to shut off the water is given. What is "reasonable notice" will vary with the facts of each case.

Section 23 provides a limitation period of 6 months or 1 year for actions brought against any persons for anything done in pursuance of the Act.

Section 24 of the Municipal Act R.S.O. 1960, chap.249 provides that two or more municipalities or parts thereof may be formed by the Ontario Municipal Board, into an inter-urban area for the joint administration therein of waterworks or water systems, which area is governed by a Board of Management having the powers of a municipal council and a local board.

Section 377(5) of the Act confers power on a municipality to enter into an agreement with one or more municipalities to provide

for the joint management and operation of water systems and for the establishment of a joint board of management therefor. Section 377(6) of the Act confers power on a municipality to enter into an agreement with one or more municipalities for the establishment, acquisition, enlargement or extension of a water system to be jointly owned by the municipalities entering into the agreement and operated for their joint use.

Section 379(1)(52) confers power on a local municipality (defined to exclude a "county") to complete, improve, alter, enlarge or extend a water works or a water supply system or any part thereof owned by the municipality and controlled and managed by it or by a public utility commission.

Under the Ontario Water Resources Commission Act, R.S.O. 1960, chap.281, s.16(1)(b), the Ontario Water Resources Commission has power to construct, acquire, provide, operate and maintain water works and under s.47(1)(g), to make regulations prescribing operating standards for water works. Such regulations have not yet been made.

Under s.30 the establishment or extension of or change in any water works requires the approval of the Commission and if such approval is not first obtained, the Commission may direct changes in the works. The Commission may require returns to be made by the owners of water works and may direct the manner in which and the facilities with which the water works shall be maintained, kept in repair and operated at all times.

Under s.39 the Commission may, on the application of one or more municipalities, provide and operate water works for the

municipality or municipalities. This is done by an agreement for a specified term of years, after which the operation and ownership of the water works is transferred to the municipality or municipalities.

I will now deal with the possible bases of liability for the supply of unsuitable water. One possible basis of liability is the doctrine of implied warranty under the Sale of Goods Act, R.S.O.1960 chap.358, s.15. This means that when a buyer of water, expressly or by implication, makes known to the supplier of the water, the particular purpose for which the water is required so as to show that the buyer relies on the supplier's skill or judgment and it is in the course of the supplier's business to sell such water, there is an implied warranty or promise on the part of the supplier that the water is reasonably fit for the purpose for which it is required. If the water is not reasonably fit for such purpose and the buyer suffers damage as a result, the supplier is liable whether or not he was negligent. Before this doctrine can be applied it must be established that the municipality or public utilities commission, which operates the water works, contracted with the user of the water to sell water to the user. The St. Lawrence case clearly holds that where water is supplied by a public utility commission or a municipality pursuant to a duty imposed by statute, for example s.55 of the Public Utilities Act, there is no contract for the sale of the water and therefore there can be no implied warranty that it is reasonably fit for the purpose for which it is sold. In addition, the Court in a dictum in the St. Lawrence case stated that at common law the supplying of a public utility, such as water, was a matter of duty and not a matter of contract.

In Munshaw Colour Service Ltd. v. City of Vancouver (1959) 31 W.W.R. 273, the Court held that there was no statutory duty upon the City of Vancouver to supply water, under the terms of the relevant statute, and the plaintiff's counsel abandoned his argument based on breach of an implied warranty that the water supplied was reasonably fit for the purpose for which it was required.

If water is supplied pursuant to a contract, it must also be shown that the plaintiff made known to the seller the purpose for which the water was required so as to show that he relied on the seller's skill and judgment and suffered damage as a result of such reliance. Several of these elements were found lacking by Chief Justice Burton in the case of Scottish Ontario & Manitoba Land Co. v. City of Toronto (1899) 26 O.A.R. 345, where the plaintiff brought an action based on breach of contract, for damages suffered when hydraulic elevators in his building were put out of order by sand in the water supplied by the defendant municipality. At p.348 Chief Justice Burton stated that there was no implied warranty even if there was a contract for the supply of water, because, "It surely cannot be said that there was any warranty that the water was fit for the purpose for which it was required. Here was a sale of an existing article upon which the purchaser had the opportunity of exercising his own judgment, and there is no fraud on the part of the sellers and even though the defect might not have been discoverable until after the water was in use, whenever it was ascertained it was open to the plaintiffs to cease to take it and prevent a damage which subsequently occurred." In other words, not only did the plaintiff not rely on the defendant municipality's skill and judgment in supplying

the water, but the damage was caused by the plaintiff's carelessness in continuing to use water which was unfit for the purpose for which it was required after the plaintiff could have discovered that the water was unfit for such purpose and have ceased to use it.

Another possible defense to liability based on implied warranty is that the water complies with the "Public Health Service Drinking Water Standards 1946" of the United States Public Health Service and therefore is reasonably fit for the purpose for which required. While these standards are not of binding effect in Canada the Court in the Munshaw case accepted them as a reasonable definition of "wholesome or ordinarily pure" water. Compliance with these Standards likely would not afford a defense to liability based on implied warranty where, pursuant to a contract to sell water, the buyer made known to the supplier that water of better quality than that specified by the Standards was needed for the buyer's particular purposes and that the buyer relied on the supplier's skill and judgment in supplying such water.

Another legal basis of liability for supplying unsuitable water is negligence of the supplier. Apart from negligence based on breach of a statutory duty, this may be generally defined as doing that which a reasonable man, in the position of the supplier of the water, would not do or omitting to do that which a reasonable man, in the position of the supplier, would do, thereby causing harm to those users who the supplier should reasonably have foreseen would be harmed. In other words, while a reasonable mistake or omission in the treatment or supply of water which causes damage to such users does not result in liability for negligence, an unreasonable mistake or omission

which causes such damage does result in liability for negligence.

The standard of reasonable care required is flexible, varying with the particular circumstances of each set of facts. It is not based on "hindsight", but on reasonable foresight at the time the alleged unreasonable act or omission took place. The application of this standard may be illustrated by reference to several cases.

In O'Dell and Mitchell v. City of London (1919) 17 O.W.N. 284, the plaintiff recovered damages for loss of goods and interference with his business alleged to have been caused by water escaping from a municipal water main. The Court held that the flooding was caused by the City's negligence in the following respects:

"1. The maintenance of the hydrant attached to the sidewalk in such a manner as to prevent the frost jacket attached thereto from performing its function properly.

2. The failure of the defendants to maintain the hydrant in question free of water and ice whereby the hydrant was prevented from operating in its proper manner.

3. Unreasonable delay in shutting off the water after the break in the main by reason of the defendant's failure to maintain a proper system of men and appliances to attend promptly to breaks in cold weather, and proper means, for example charts, for the purpose of enabling repair gangs without undue delay, to locate the valve or valves to be shut off."

The Court rejected the City's defense that the main break was caused by an Act of God for which the City was not responsible, on the ground that this defense is available only if it had been shown

that the City had taken all reasonable precautions and that the damages complained of not only might, but must have happened independently of their neglect.

In the case of Canadian Pacific Railway Company v. The City of Toronto (1954) O.R. 535, a cast iron water main laid in 1912 by the defendant City burst in 1950, causing extensive flooding of the plaintiff's premises with damage to its property and equipment and to goods in its custody. The plaintiff claimed damages both on the ground of negligence in the installation of the main and on the ground that Coxon, an employee of the defendant had, through incompetence, failed to turn off the water as quickly as it should have been turned off. The break occurred at 3.40 a.m. and the water was shut off at 6.10 a.m. after about 7 million gallons had escaped. There was no delay in reporting the break or in getting an emergency crew to the scene. Coxon, in charge of the crew, mistakenly assumed that the break had been in a 6" main rather than in a 36" main and, after the crew had worked for about 1½ hours trying to locate the break, sent for his supervisor, Atcheson, who quickly located the break and turned off the water. The Court held that there was no negligence. The pipe had been laid in accordance with sound engineering practice in 1912 and the fact that subsequent research, the results of which were first published 30 years later, had disclosed that cast iron was not as suitable for large pipes as had been thought, did not mean the defendant was negligent in failing to take up and replace about 35 miles of cast iron water mains.

With respect to shutting the water off, Mr. Justice Judson at p.541 said, "It would be very easy for me sitting with the photo-

graphs in front of me to say that Coxon should have suspected at once that the break was in the 36" main and not in the 6" domestic main. But the problem that faced Coxon was a difficult one. There was a man with 22 years experience in the Water Works Department and an excellent record. He had been on permanent service for the emergency department for six months before this break occurred and for some years before that he had been doing relief work with the emergency service. He was qualified by training and experience to do the job to which he was assigned. A man who goes to deal with a break of this kind has to size up the situation and then act according to his judgment. I am satisfied that Coxon put forward his best efforts and used his best judgment. I am equally satisfied that his best judgment was not equal to that which would have been used by Atcheson if he had been on the job from the beginning. But Atcheson's knowledge of the system was something out of the ordinary. It would be unreasonable to expect the Water Works Department to have on duty at all times a man with the qualifications of an engineer or the ability of this particular superintendent. I think Coxon was a reasonably competent man on the job to which he was assigned and that he did the job to the best of his ability and with diligence. Both Mr. Fitzgerald and Mr. Storey say that 1½ hours would be a reasonable time within which to deal with a situation of this kind. It may be that Coxon should have summoned assistance before he did, but I cannot find the City employed an incompetent servant or that he did his job incompetently or negligently."

In an English case Read v. Croydon Corporation (1938) 4 A.E.R. 631, the defendant corporation owned and operated two wells from

which it supplied water to the surrounding borough. The adult and infant plaintiffs claimed damages as a result of contacting typhoid fever from drinking water supplied from the wells. The disease was introduced into the water either from the gathering ground or by a carrier of the disease described as "Case A", who was working in the wells during repairs. The Court absolved the defendant from negligence in selection of the gathering ground and of the workmen, but held there was negligence in omitting precautions in the form of continual analysis of the water and a systematic policy of chlorination and filtration, during the repair of one well. At p.646 Mr. Justice Stable states "In my judgment the Corporation. . . failed in its duty in two major respects. From July 1936 when the chlorinating plant first came into use, the extent to which this precaution was enforced was haphazard, ill-considered and inadequate. The decision at the moment of greatest peril, when the water was being put into supply while the men were working on the well, to omit the customary precautions of filtration and chlorination, looked at, not in the light of what we know now, but in the light of what was known then, was in my judgment inexcusable....... Throughout the whole of this case no evidence was adduced.....to indicate that any one member of that Committee made any enquiry or took any step whatever to formulate any established policy in connection with chlorination or to set up machinery to put that policy into effect or to provide a proper system of supervision and inspection to insure that any policy that was adopted was being efficiently, regularly, systematically carried out....... While the probability looked at from the point of time immediately preceding these happenings that the water could be infected by Case A, was

utterly remote, the bacteriologist or water engineer responsible for the supply of water to an urban community, if he discharges his duties properly, must be constantly on his guard against innumerable risks. Though the chance of any one of the risks materialising into a peril is remote, collectively and in the aggregate the danger is real and substantial." At p.643 he states "No log book was kept showing whether or not chlorination was enforced at any particular time or when it was enforced or the dosage that was adopted. It is obvious that the practice of chlorinating the water or of increasing the dose after and in consequence of an unsatisfactory analysis, was not satisfactory in as much as that chlorination was thus used as a remedy for an existing evil rather than as a preventive of a potential danger which the experience of years had proved to have threatened."

In Munshaw Colour Service Ltd. v. City of Vancouver (1959) 31 W.W.R. 273, the plaintiff carried on the business of photo finishing and film developing and used a large volume of water in its automatic processing machines, which it purchased from the defendant, the City of Vancouver. Films were damaged in the wash tanks by sediment in water which contained quantities of silt and a very high content of iron oxide. The plaintiff had a filter system which was ordinarily effective to eliminate from the water supplied particles of sediment larger in size than 25 microns, but in this case the filter system broke down and permitted larger particles to enter the tanks. On the particular day when the films were damaged, the City had been carrying on sewer clearing operations by a process of "dragging" and "flushing" the sewer pipes with water from a hydrant located about 1250' from the plaintiff's premises. It was established in evidence that the use of water from hydrants for this purpose is a common

practice in Vancouver and other large cities in Canada and the United States and no warning of the sewer clearing operations was given by the City to the plaintiff. It was also established as inferences from the evidence, that:

1. The City knew, or ought to have known, that there was sediment consisting of particles of sand and rust in its water mains adjacent to or in the vicinity of the plaintiff's premises.
2. The City knew, or ought to have known, that the use of hydrants for flushing sewers within 1250 ft. of the plaintiff's premises was likely to cause the sediment to be disturbed or stirred up so that it might, with the flow of water from its mains, enter the service pipes of the plaintiff.

No evidence was adduced from which it could be inferred that the sediment in the water originated on the plaintiff's premises or in its own pipes and the inference was drawn that the sediment came into the tanks from the mains of the City's water system. The Court held that the plaintiff had established negligence by the City, that is acts and omissions which were unreasonable in the light of what the City knew or should have known about the sediment and the sewer clearing operation. The negligence consisted of:

(a) supplying water from its mains which was not wholesome or ordinarily pure and was unfit for ordinary domestic purposes or ordinary human consumption because it did not comply with the "Public Health Service Drinking Water Standards, 1946";

(b) permitting a hydrant in the vicinity of the plaintiff's premises to be turned on when it knew, or ought to have known, that the sediment, know to be in its mains, was thereby likely to be released and likely to result in delivery to the plaintiff

of water which was not of proper quality;

(c) in failing either to take steps to remove the sediment from its mains by means not injurious to the plaintiff or to warn the plaintiff in advance that the sewer flushing operations by the City were liable to result in delivery of water which was not of proper quality.

The importance of this case lies in the following decisions of the Court:

1. There being no standard of quality prescribed by Provincial Statute or by contract, the duty of a municipality or a public utilities commission at common law, is to supply water that is wholesome and ordinarily pure as distinguished from water that is chemically pure. The water must be fit for ordinary human consumption and ordinary domestic purposes. The duty does not extend to supplying water suitable for the particular purpose of any applicant for water whose operations require water of a particular standard of quality greater than that required by the term "wholesome and ordinarily pure". For example, if water supplied to a live bait dealer was fit for ordinary human consumption and ordinary domestic purposes, but was unfit for the survival of the live bait and caused the death of the bait, there would likely be no breach of duty and no liability for negligence. However, there might be liability for breach of contract or implied warranty under the conditions previously discussed.
2. The Public Health Service Drinking Water Standards, 1946, of the United States Public Health Service furnish a reasonable and acceptable definition of what is meant by "wholesome and ordinarily

pure water".

3. The City pleaded that any damage suffered by the plaintiff was caused by the plaintiff's contributory negligence in not installing a filtering system capable of making the water supply fit for the plaintiff's particular purposes. The plaintiff did not ask the City to supply it with water suitable for the plaintiff's special purposes and, knowing the water supplied for ordinary domestic purposes was not suitable for its purposes, the plaintiff had installed an elaborate filter system. The Court held that the plaintiff was entitled to "wholesome and ordinarily pure" water from the City and that the damage was caused not by the breakdown of the plaintiff's filter system but by the negligent supply of water which fell below the required standard of quality. In other words, the Court held that the plaintiff had not caused or materially contributed to its damage by omitting to do anything that a reasonable man would do or by doing something which a reasonable man would not do, under the circumstances.

This case illustrates that liability may result from merely following the common practice of sewer clearing without exercising reasonable foresight as to possible harm to nearby users of water. It would have been possible to avoid liability in the Munshaw case by using the hydrant for sewer clearing at a time when it was known that the plaintiff was not carrying on operations, such as at night.

In Ontario there is no standard of quality prescribed by any statute for the water supplied by a municipality or by a public utilities

commission. Section 47(1)(g) of the Ontario Water Resources Commission Act, R.S.O. 1960, chap.281 provides that, subject to the approval of the Lieutenant-Governor in Council, the Ontario Water Resources Commission may make regulations "prescribing standards of quality for potable and other water supplies....", but no such regulations have yet been made by the Commission. Section 16(1) of the same Act provides that it is the function of the Commission and it has power "(a) to control and regulate the.....treatment..... of water for public purposes and to make orders with respect thereto." This power to make orders relates to specific instances of water treatment and does not relate to a general standard of quality for water used for public purposes. The Commission has made several mandatory orders under this section relating to water treatment in specific cases.

The duty of the water works operator is relative to the treatment and supply facilities with which he has been provided, to the conditions which he knows about or reasonably should know about in his particular locality, to the past experience in the locality with water pollution and to the advice received from bodies like the Ontario Water Resources Commission and the Department of Health. To be held liable for negligence he need now know that the water supply falls below the required standard of quality. It is sufficient for liability to be established if a reasonable man in his position and knowing what he knows, would have known that the water is below the required standard and would have taken precautions which he did not take. For example, in many water works there are no facilities for chlorination or other chemical treatment of the water or for filtration. Raw water is pumped from a well into the distribution

system. In small communities where there has been no previous history of polluted water, it may be reasonable to take and test only two samples a month of the raw water. But if the water works operator knows, or reasonably should know, of factors which might adversely affect the quality of the water it would be necessary for him to increase the number of samples for testing. Moreover, he must carefully inspect the well itself to see if there are cracks or other construction defects that might allow substances into the water that might pollute it. If there are repairs to be made or if the well area has been flooded recently it may well be necessary for him to stop the supply of water from the well and manually chlorinate it before using it again. It may also be necessary to take these precautions for the distribution system and even to take steps to warn the inhabitants if untreated water has entered the distribution system. It is reasonable that in every community the water works operator should be familiar with emergency chlorination procedure and have the equipment available for carrying out such procedure if necessary. The water works operator must be on constant alert to the ever present and ever changing threats to the quality of the water supplied. If he takes all reasonable precautions, which will vary with what he knows or should know about local conditions, he will not be liable for negligence even though the municipality or public utilities commission may be liable for not providing him with adequate treatment facilities if such facilities should reasonably have been provided.

In water works where chlorination is carried out, the following are some of the duties which, if not performed or not performed

properly, might cause water of unsuitable quality and resulting damage and liability for negligence. The operator must judge as to how often he should check the chlorine content of the water in order to determine if the proper chlorine residual is being continuously maintained. If the quality of the water is subject to frequent change, as in Port Colborne, the operator may need to check the chlorine residual by hourly sampling. If the quality of the water is quite stable, as in St. Catherines, daily sampling may be sufficient. He must interpret the results of his checks correctly and he must maintain the correct amount of chlorine residual in the water at all times by properly adjusting the quantities added to variations in the quality and quantity of the water supplied. He must have a sufficient supply of chlorine on hand at all times and not only accurately add the chlorine to the water, but make certain that the chlorine is being added continuously. He must ensure that the chlorination equipment is working at all times and that it is connected properly so that for example, in the event of a fire, unchlorinated water will not escape into the water mains by means of the fire pump. He must also ensure that sufficient chlorine is removed so that the water will not have an offensive taste. Where proximity to oil refineries, as in Port Credit, or coal deposits, as in Port Colborne, creates a risk of chemicals, such as phenol, entering the water and either alone or in combination with the chlorine residual causing an offensive taste, it is necessary to systematically and frequently sample the water and to add the correct amount of a chemical such as chlorindioxide to eliminate the offensive taste. It may even be necessary temporarily to turn off the water supply and obtain an alternative supply.

With respect to filtration, the standard of care required from the water works operator is relative to the facilities with which he has been supplied. If he has been supplied with a properly designed filtration plant, he will be responsible for supplying water which meets the turbidity standard of the Public Health Service Drinking Water Standards, 1946. If he has not been supplied with proper filtration equipment he will not of course be responsible for meeting the standard, but he will be responsible for maintaining the standard of turbidity to the full extent of the filtration equipment available to him. Where properly designed filtration equipment is available the responsibility of the operator would also extend to checking the PH regularly so that there will be no probability of damage to service pipes from excess acidity due to the addition of conditioning chemicals. Not only is filtration important from the standpoint of taste and appearance, but inadequate filtration and excessive turbidity of the water have a direct adverse effect on the bacteriological quality of the water and therefore on the maintenance of a proper chlorine residual.

It may be difficult to establish liability for negligence where there is use of water with an offensive taste or appearance because of inadequate chemical treatment or inadequate filtration. The reason is that although such water supplied under such conditions is a breach of the common law duty of the supplier, an argument may be possible that the damage, if any, was caused or materially contributed to, not by the unsuitable water but by the contributory negligence of the user. Such an argument is possible only if the user could reasonably have inspected the water or observed that the taste or

appearance were offensive and could have stopped its use before any damage was caused. The law of negligence does not compensate for reasonably avoidable self-inflicted damage even though the water supplied is below the required standard of quality because of unreasonable acts or omissions in its supply and treatment.

It should also be emphasized that proof of damage caused by the breach of duty to supply water of the required standard is an essential element of liability for negligence. This element, as other elements in negligence, need not be proved beyond a reasonable doubt. As Lord Chancellor Loreburn stated in Richard Evans & Company v. Astley (1911) A.C. 674 at p.678 "It is of course impossible to lay down in words any scale of standards by which you can measure the degree of proof which will suffice to support a particular conclusion of facts. The applicant must prove his case. This does not mean that he must demonstrate his case. If the more probable conclusion is that for which he contends and there is anything pointing to it, then there is evidence for a Court to act upon. Any conclusion short of certainty may be miscalled conjecture or surmise, but Courts, like individuals, habitually act upon a balance of probabilities."

The following case sets out some of the requirements of proof of damage which must be met in an action for negligence. In McQueen v. City of Owen Sound (1927) O.W.N. 383 an action was brought for damages in respect of injuries suffered by the plaintiff from typhoid fever alleged to have been contacted from drinking unsuitable water supplied by the defendant. The trial judge found that the plaintiff's illness was caused by the negligent supply to her by the defendant of contaminated water. At p.384 the Court of Appeal,

in reversing this decision, stated "There was no direct evidence that the water supplied to the plaintiff by the defendant caused her illness and the onus was upon her to prove such facts as would warrant the Court in drawing the inference that of all reasonably possible causes, the defendant's negligence was the cause. Unless the water contained typhoid bacilli, it could not cause typhoid fever and there was no direct or indirect evidence that it contained typhoid bacilli. The finding that her illness was caused by contaminated water appeared to be mere conjecture and not a legitimate inference from true facts." The Court also pointed out that water, milk, dust and even people are frequent carriers of typhoid bacilli. Flies may carry the bacilli and impregnate water, milk and food with it. The Court held that the action failed from the want of direct or indirect evidence that the water supplied to the plaintiff contained typhoid bacilli and also because, even if the water did contain typhoid bacilli, the evidence did not warrant the inference that of all possible causes of the plaintiff's illness, the most probable one was contaminated water.

WATER BACTERIOLOGY

by

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WATER BACTERIOLOGY

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BACTERIA

The word bacteria is familiar to most people even though few are aware of their appearance or function in nature. Bacteria are often thought of as synonomous to disease organisms or associated with the cause of diseases, but beyond this little more is generally known. It is true that many bacteria are the caustive agents of various diseases and infections but many many more are of value to man both commercially and in nature through their normal activity. Several large industries cater to the requirements of micro-organisms in an attempt to capitalize on their abilities to produce products such as alcohol, organic acids and antibiotics which are necessary in the life of a community. Only through the powers of these microbes is the inert gas nitrogen available to animal and plant life. Nitrogen does not exist in nature as a mineral deposit in the earth's crust, but as a gas in the planet's atmosphere. The fixed form of nitrogen exists as deposits resulting from decay of masses of nitrogen fixing bacteria. The mineralization of dead organic matter in the soil, the purification of waters, and the decay of vegetation is made possible through the work of these microscopic organisms. Even much of the process of the digestion of food within the animal body is brought about by the varied activities of bacteria. Imagine the chaos in nature if dead vegetation and animal life were not caused by decay by micro-organisms.

Bacteria are so wide-spread in nature that there is scarely a medium that does not support a particular flora of its own. For our purposes a definitition of bacteria will include all single-celled microscopic plants, lacking true chlorophyl and capable of reproduction.

BACTERIA IN WATER

A discussion of water bacteriology naturally falls into two categories, first, that of disease and associated organisms in water, and, second, of all other organisms that cause trouble in water systems, treatment processes and in ground surface waters.

An impure or non-potable water may be defined as one that is not fit for human consumption primarily because of the possible presence of pathogenic (disease) micro-organisms. Relatively few species of organisms are held to be indicative of sewage pollution. The most important of these are the coliforms, Escherichia coli, Aerobacter aerogenes, Streptococcus pyogenes, and Clostridium welchii. These organisms are quite constantly present in the intestines of man and animals. When they are found in considerable numbers in water, it may be generally concluded that there is contamination with sewage, inasmuch as they do not often continue to multiply outside of the body for very long periods after their elimination.

Disease organisms may gain access to a water supply from the air, soil, animal discharges, contact with diseased material and from sewage pollution. Whatever the disease organism, it does not

occur naturally in water, nor will it exist there for long periods. These micro-organisms must therefore be transmitted to water from some outside source. Nor are intestinal organisms, such as those causing typhoid and dysentery, the only disease producing bacteria occurring periodically in polluted water. Bacteria causing tuberculosis, plague, tetanus and virus diseases such as poliomyelitis are also present at times in water in numbers to cause concern. Too often this latter group is completely ignored. The typhoid organism causes that accute disease when it gains entrance to the intestine by oral ingestion, where drinking water can serve as a means of transportation. However, it must be remembered that water used in washing may also transport other infectious organisms, such as the tetanus bacilli, to a wound which could be as injurious to humans as typhoid. Therefore, in estimating pollution, not only is the presence of sewage to be considered, but contact of water with animals and man as well.

A pure water supply, however, seems to affect the general health of a community and to decrease its death rate wholly apart from the decrease due to the elimination of the specific diseases mentioned above. It has been noted, for example, that when a city changes from a contaminated to a pure supply, there is not only a marked decrease in the typhoid death rate, but also in some instances decreases are noted in the number of deaths from tuberculosis, pneumonia, and other diseases. In practically every instance there is a decided decrease in the total death rate. This phenomenon must be due to one of two causes. Either, disease not ordinarily regarded as being carried by water are in a certain

percentage of cases so transmitted, or the use of an impure water supply so affects the average health of a community that the individuals become more readily susceptible to other diseases. It is probable that the latter is the true explanation.

The other organisms that should be included in any discussion of water bacteriology, are those present as a result of organic or inorganic substances in water. Taste and odour problems and slime growths are undesirable since they impair water movement in mains and subsequently become a nuisance to the supplier and consumer. The organisms involved here are of the sulphur and iron groups in particular, as well as all the others generally present in water systems.

Potable water therefore may be said to contain no disease producing organisms and no organic or inorganic substances deleterious to health.

DETECTING POLLUTION

It has long been recognized that the presence of sewage in water can only be detected by bacteriological methods. Suspended solids, nitrates, Biochemical oxygen demand (BOD) and other chemical determinations do not positively identify sewage pollution of water, though they may help to characterize the pollutant.

Many wonder why disease organisms themselves are not used to indicate unsafe water. One of the major reasons for this is that disease organisms abound in polluted water in small numbers making

their detection difficult unless large volumes of water are examined.

In the bacteriological determinations for sewage pollution, a group of bacteria that are quantitatively proportional to the amount of sewage present is commonly used. These indicator organisms are called coliforms. Coliforms were chosen over the other types of intestinal bacteria mentioned because they most closely fit the definition of the ideal indicator. (Appendix I). Other organisms have been suggested for use as sewage pollution indicators, but most of these have serious shortcomings.

In nature, coliforms inhabit part of the intestine, forming one of the largest group of organisms normally populating the human and animal digestive systems. In polluted water, their density is in rough proportion to the degree of sewage pollution. Coliforms occur constantly in large numbers in human and animal discharges in comparison to pathogenic bacteria which occur only periodically in quantity. They are easily detected by rapid routine procedures to be discussed, and are harmless to humans under normal circumstances. Therefore, by watching for their appearance in water through routine determinations, information of the presence or absence of sewage pollution is obtained before a dangerous level of pollution exists.

The coliform group of micro-organisms has a longer survival time in water than does the group of intestinal pathogenes. This

means that their presence indicates not only current but also past pollution.

Some disadvantages in the use of coliform bacteria to detect pollution are nevertheless evident. Foremost among these is the fact that some members of the coliform family occur naturally in soil and on vegetation, as well as in the human and animal body. The existence of members of the coliform group in water would then be interpreted to mean that that supply contained either sewage or surface soil. This knowledge enhances the power of the indicator, since under conditions of flood, heavy rains, or disturbance of soil, by animal or man, the presence of coliforms would indicate that disease organisms in the surrounding environment had access to the water supply. As mentioned earlier soil contains natural and animal-borne pathogens that could cause serious diseases should they enter the human body. Judgement regarding the type of contamination is easily made when a record of sampling conditions and a coliform count are available.

ENUMERATING COLIFORM ORGANISMS

Indicated Number

After their characteristics were determined, a routine method to count coliforms was established. This method is presently known as the Indicated Number. In this procedure, a sample of water is diluted according to a predetermined scheme and a portion of each dilution is transferred to tubes containing a specific nutrient

broth. This solution contains growth factors required by the indicator organism, so that when it is present in the transplanted water sample, it will, by growing, produce a visible change in the tube of broth, and when absent the tube will remain unchanged. By this method, it is possible to determine that point in successive dilutions where coliforms are diluted out of the picture. A simple mathematical calculation will then give the number of coliforms per 100 ml. of the sample. Because of the application of mathematics and the use of dilutions, the numerical result from this test gives only an approximation of the number of coliforms. Its reproducibility is poor, the results deviating from each other on occasion by as much as 1,000 per 100 ml. An Indicated Number of 1,000 per 100 ml. of sample means that coliforms are present in .1 ml. though absent in .01 ml. quantity of the sample. This method is used to a greater extent in heavily polluted waters.

Most Probable Number

The Most Probable Number procedure is a variation of the Indicated Number method were through the application of statistical methods, an attempt has been made to obtain a more accurate enumeration of the coliform organism. This procedure involves the planting of replicate (generally three or five) parallel decimal dilutions of sample water in a special nutrient broth, where, following a confirmation test, a statistical table is consulted from which the number of coliforms per 100 ml. is directly read. This analyses takes a minimum of four (4) days. The result is merely an index of the number of coliform bacteria which, more probably than any other number, would give the results shown by

the laboratory examination. It is not an actual enumeration of the coliform bacteria in any given volume of samples. The value of the most probable number procedure lies primarily in giving a number or code which approximates the actual number of coliforms present. All results derived by this method may be directly compared.

It has decided advantages over the Indicated Number method since its results are more closely reproducible, and it is valuable when used in conjunction with the proper safety standards.

Membrane Filter

In recent years following the introduction of the Membrane Filter disc, a new and more rapid and more accurate method for the isolation and identification of coliforms has been developed. The method allows bacteria to be filtered from a liquid and cultured by the application of a suitable nutrient solution on the surface of the filter leaf.

This new technique has several advantages over the other methods. Large samples can be processed more easily assuring a more accurate determination, and results can be obtained in a period of one (1) day. A direct count of organisms is obtained where no mathematical calculations are generally required.

The Membrane Filter technique has been accepted as an alternative to the Most Probable Number determination in the United States of America and its use in routine testing is gaining favour in many government agencies. Drinking water standards for membrane

filter results have been established in the United States. The Water Resources Commission standards will be dealt with later.

The coliform count obtained by this method is an exact measure of the organisms in the sample. The results produced by the Membrane Filter technique are lower than that of both the Most Probable Number and Indicated Number, but have proven to be more truly representative of the actual number of coliforms in samples. A factor to enable the conversion of the Most Probable Number to the Membrane Filter results may be established only for a single body of water but will vary greatly with the character of the water. Therefore, the Most Probable Number count may only be compared in a general way with the Membrane Filter count.

INTERPRETATION

Most Probable Number and/or Membrane Filter coliform data of individual water samples are interpreted to mean that:

1. when total coliform densities are one or less per 100 ml. of sample, the water is safe for human and animal consumption,

2. when total coliform counts are in excess of one per 100 ml., the water is polluted and should be reexamined to establish the extent of pollution (it may require treatment before consumption),

3. where large numbers of coliforms (greater than ten per 100 ml.) are present, gross pollution exists. This water should be treated prior to consumption and measures to detect and check pollution should be enforced.

It must be remembered that there is always the possibility of the presence of enteric pathogens when the water contains coliforms.

A satisfactory report on the bacteriological quality of a water supply is only obtained when frequent regular samples are analyzed and data are accumulated that can be used as background material in the event of poor individual samples. These data are of great importance in establishing the effect of seasonal variations and other factors on the water quality.

Following poor samples, only the analyses of a series of well chosen samples will establish the water quality and aid in locating the source of contamination. Lengthy standards have been prepared to control the quality of water in this instance. When routine sampling programmes are established for water plants in Ontario these standards will then be introduced. The main recommendation resulting from these standards is to emphasize the importance of immediate corrective measures and the commencement of a daily sampling programme, in the trouble areas, until two consecutive negative samples are obtained.

OTHER POLLUTION INDICATORS

An examination for the organism called Escherichia coli is used by some laboratories to indicate non-potable water. This organism, the same as B. coli with a new name, is one member of the coliform group which is present in fecal material. It may be used to indicate recent pollution or to confirm coliform data, but since its exclusion from water does not indicate a safe water, E. coli should not be used alone to determine sewage pollution. Together with the total coliform analyses, it gives additional information of the character of the pollutant. Among other disadvantages in the use of E. colio to indicate pollution, the density of this organism in polluted waters is generally low, substantially decreasing the chances of detecting it in mildly polluted waters.

Another group of bacteria that will be discussed more fully in the next phase of this course is the fecal Streptococcus group. The detection of the present of this organism in water will aid mainly in evaluating the recency of pollution.

NUISANCE ORGANISMS IN WATER

The nuisance micro-organisms (other than algae) that generally occur in water fall into the following groups:

1. Total bacterial population,
2. Iron and magnesium bacteria,
3. Slime bacteria including molds,
4. Sulphur and sulphate reducing bacteria, and
5. Actinomycetes - the organisms responsible for the characteristic smell of earth.

All of these organisms grow in water as a result of a particular set of conditions created in the water. These have been studied by many research workers though little practical information is available from their investigations.

The identification of many of these bio-fouling organisms is very difficult though some of their properties may be determined. Chemical and physical contact have not been widely studied, with the result that chlorination and good-housekeeping still remain the only available effective means of treatment.

NOTE: Slides on Nuisance Organisms will be shown.

APPENDIX I

Characteristics of Coliforms as a Pollution Indicator Compared to the Ideal

	The Ideal Indicator	The Coliform Indicator
1.	gives uniform results with all types of water	is affected at times by the type of water
2.	is never present in safe water	is absent in safe water
3.	density is proportional to fecal pollution	density is roughly proportional to fecal pollution, and is eliminated in large numbers in fecal wastes
4.	is harmless to man and animals	is harmless to man and animals except in very rare cases
5.	has a greater survival time in water than do disease organisms	is more resistant than most disease producing organisms.
6.	disappears rapidly from water after the death or destruction of disease bacteria	generally dies off rapidly. However, some species may grow in polluted water.
7.	distribution is restricted to one type of waste	is widely distributed in nature but always present in human and animal discharges
8.	is easily detected by routine methods	is relatively easy to detect by routine procedures

ELEMENTARY WATER CHEMISTRY

by

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An Address To
The Ontario Water Resources Commission
Basic Water Works Course
Toronto, Ontario
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Chemistry is one of our oldest sciences being allied very closely with the science of physics. There is no fine dividing line between these sciences, and without mathematics, neither would be of much practical use. The elementary chemistry discussed, is therefore to a great extent physical chemistry, with some examples of the practical uses chemists make of mathematics.

The first, is in defining units. Because water chemists perform their analysis by measuring the weight of a substance in a measured volume of sample, the scientifically accurate way of expressing results is in milligrams per litre (mgms/L), (weight per volume units). These are the commonly used laboratory units, and for those who are acquainted with what milligram weights and litre volumes actually are, concentrations expressed in mgms/L can be visualized. A better grasp of the quantities is possible when the less precise term, parts per million (p.p.m.) is used, and this is our preference. It is at most, only slightly inaccurate. One litre of pure water at $4^{\circ}C$ weighs 100 gms, therefore at $4^{\circ}C$

$$\frac{1 \text{ mgm}}{1 \text{ litre}} = \frac{.001 \text{ gram}}{1000 \text{ grams}} = \frac{1 \text{ gram}}{1{,}000{,}000 \text{ grams}} \qquad (1 \text{ p.p.m.})$$

At room temperature, because of expansion, 1 litre holds very slightly less than 1000 grams of water, actually about 999.9, and the hotter the water is, the less 1 litre will hold.

Also, water that is very impure (a strong solution or suspension) may weigh a good deal more than 1000 grams per litre, because of the weight of material in it.

This factor needs to be allowed for when analysing dense sludges of slurries. The best way to report analyses of these materials correctly is to dry a measured volume of the sludge, weigh the solids content, and calculate a 'dried solids' factor. This is then used to convert all the (mgm/L) values of other tests to a mathematically correct "% of dried solids value" which is usually the most appropriate way to report sludge and slurry analyses.

For practical purposes then, when the sample is at most a dilute solution in water, and volumes are measured at room temperature,

1 mgm/L is closely equivalent to 1 gram/million grams (1 p.p.m.).

One practical purpose is this; one can immediately transpose into any weight unit at all

1 grain per million grains, or

1 ounce per million ounces, or

1 ton per million tons.

The most useful is 1 pound per million pounds. Since, due to our advantageous Imperial system, 1 gallon of water weighs 10 pounds, then, 1 ppm = 1 pound per 100,000 Imp. Gals.
or for chlorine dosages in tenths of a part per million.

1/10 ppm = 1 lb. per 1,000,000 Imp. Gals.

The factor for an older water treatment unit, sometimes still used is: 1 Grain per Imp. Gal = 14.25 ppm

1 Grain per U.S. Gal = 17.12 ppm

Other useful conversions from scientific to practical units are: for water at 4°C

	1 litre	=	1000 grams	= 2.2 lbs.
÷ 1,000	1 millilitre	=	1 gram	= 0.0353 ounces
÷ 1,000	1 microlitre (λ, lambda)	=	1 milligram	
÷ 1,000			1 microgram	(γ, gamma)
	1 microgram/ml		(γ/ml)	= 1 mgm/litre = ppm.

$\frac{\text{Thus comparator disc readings in micrograms}}{\text{Volume of sample measured in ml}}$ = ppm directly.

also 1% $= \frac{1}{100}$ or $\frac{10,000}{1,000,000}$ or 10,000 ppm.

Most texts have tables for converting units. The most comprehensive is a free pocket book given out by Merck & Co. "Tables of Conversion Factors, Weights and Measures".

Other basic units of chemistry are that, in equations

Symbol		Quantity
H	=	1 gram of hydrogen
O	=	16 grams of oxyden
thus OH	=	17 grams of hydroxyl
and HOH (or H_2O)	=	18 grams of water

Water is, in fact, a very unusual substance, although so commonplace that it's unusual properties are overlooked. These properties are a result of its chemical structure.

A water molecule H-O-H is formed of three elemental particles held together by chemical bonds. These bonds result from the charges in the particles themselves. Oxygen has a positive nucleous, balanced in charge by an inner pair and an outer layer of six electrons surrounding the nucleous. The inner pair are evenly balanced. However, among the outer six there is room for two more, eight electrons all told, to form an evenly distributed outer layer, and oxygen tends strongly to unite with elements that have electrons to spare. Such is hydrogen, a positive nucleous balanced in charge by <u>one</u> electron. One oxygen atom then will unite with two hydrogens atoms "sharing" an electron with each, and each of the three atoms then has an almost balanced layer of paired electrons.

I say almost because the charges on the whole water molecule are still slightly lopsided, with two pairs of negative electrons alone at one end, and at the other end two pairs of electrons shared with and masked by two hydrogen atoms whose positive nucleous is projecting out. This imbalance is termed "polar", the molecule as a whole tends to act as if it had "poles".

The arrangement of hydrogen atoms and paired electrons <u>surrounds</u> the oxygen nucleous in a tetrahedron shape.

The exposed pairs of electrons tend to attract positive charges. Thus the positive hydrogen on other water molecules

(and the positive pole on polar compounds in general) are attracted to these paired electrons and held there. These 'hydrogen bonds', between molecules of water, are about 6% as strong as the oxygen-hydrogen bonds inside the molecule.

The properties of water arise from the hydrogen bonding and the tetrahedral arrangement of electron pairs around the oxygen atom.

To break a bond requires energy, and in the formation of a bond energy is released, similar to static electricity or magnetism. "Like repels and unlike attracts". Attraction can be used to do work (release energy), and the attraction can only be broken by exerting force (using energy).

Take the physical state of H_2O. In water, this tendency to bond together is limited, is offset by heat. It is commonly explained that heat makes the molecules active, they bounce around so that less of the hydrogen bonds are formed. The hotter the water, the more thermal activity, the less bonding, and thus the water expands. The heat capacity absorbed in breaking these bonds (the heat required to raise water one degree) is the highest of any substance.

At the critical temperature of 212^oF the loosely grouped molecules in liquid water make an abrupt transition to freely moving individual molecules, as a gas, steam. The abrupt transition requires a lot of thermal energy to break all the hydrogen bonds and explains why water has such a high heat

of evaporation (536 calories/gram). As steam or water vapour is condensed the reformation of the bonds release the same amount of energy.

As water is cooled further and begins to form ice, all of the molecules tend to be attracted to one another by hydrogen bonds and a rigid lattice-work structure of molecule bonded to molecule solidifies. This rigid structure, full of voids, requires slightly more volume than the groups of bonded molecules in water which have some possibility of overlapping into one another, "nesting". Thus ice expands 10% on freezing, at the same time releasing energy as the bonds are formed. The dire consequences of overlooking the tremendous power of the expansion of ice are well known to us all. Very few containers, be they engine-blocks or steel pipe, can withstand the pressures formed.

The fact that ice is lighter than water, and that the heat capacities of water are high have had consequences for life on this planet that are astounding when considered. The major reason our temperatures vary as little as they do is because of the tempering effects of the cooling, heating, freezing and evaporation of water. This mineral covers three-fourths of the earth's surface, sometimes to a depth of six miles, and there may be as much as 50,000 tons of water vapour above one square mile of land surface. An only slight reduction of the heat capacities of water could double our climatic temperature range from 0 - 100^{o}F to say 50 to $\pm$150^{o}F.

Presuming that humans could survive, what would become of our food organisms, plant and animal crops, or of our forests. We would follow them into extinction and our "temperate" regions would become deserts.

Consider even the consequences of ice being heavier than water. Rivers and lakes would freeze from the bottom, would warm from the top, and ice would likely persist year round on our lake beds. The twice annual turnover of our lakes, which takes place spring and fall when the upper strata of water warms or cools to the same temperature (and density) as the water beneath, would not occur, and the nutrients entering our lakes would settle out and forever be lost in the bottom ice. Fish and most aquatic organisms would perish.

Other properties of water which have high values attributable to hydrogen bonding are well known to any one who has dived from a height. The combined resistances of the high density, surface tension and viscosity of water provide an impact similar to that of cement if a poor entry is made. Think how much easier it would be to dive into a liquid similar to gasoline, light, mobile, and with low film tension, and how much harder one would hit the bottom of the tank!

The chemistry of water is mainly governed by the ability that water has to dissociate.

$$H_2O \rightleftharpoons H^+ + OH'$$

A very few hydrogen nucleous particles can break away from the whole molecule, each leaving it's electron behind. This loss of a negative electron leaves a positively charged (H^+) hydrogen ion. The remainder of the molecule which retains the electron becomes negatively charged forming an (OH') hydroxyl ion.

At any one time, only 1 water molecule in every 550 million is dissociated. At room temperature a relation holds between the hydrogen and hydroxyl ions. Their concentrations, expressed as H^+ and OH' symbols (see units) when multiplied together always equal

$$\frac{1}{100{,}000{,}000{,}000{,}000} \quad \text{or} \quad \frac{1}{10 \times 10 \ldots\ (14 \text{ times})} \quad \text{or} \quad \frac{1}{10^{14}}$$

In absolutely pure water the hydrogen and hydroxyl ion concentrations are equal.

$H^+ = OH'$ since one of each is formed from each molecule of water. The concentration of each is then

$$\frac{1}{10^{7}} \quad \text{since} \quad \frac{1}{10^{7}} \times \frac{1}{10^{7}} = \frac{1}{10^{14}}$$

If either an acid or alkali is added (H^+ or OH') then the dissociation is altered to form water and the product of the new concentrations of H^+ and OH' still = $\frac{1}{10^{14}}$. Thus when H^+ is increased OH' decreases proportionately.

When $H^+ = OH'$ the solution is neutral

When H^+ exceeds OH' the solution is acid

When OH' exceeds H^+ the solution is basic

Concentrations by weight Hydrogen	Concentrations by weight Hydroxyl	H^+ Concentration per litre	OH' Concentration per litre	pH
1%		10		-1
1,000 ppm		1		0
100 ppm		1/10		1
10 ppm		1/100		2
1 ppm		1/1000		3
100 ppb		1/10,000	etc.	4
10 ppb		1/100,000	1/1,000,000,000	5
1 ppb		1/1,000,000	1/100,000,000	6
0.1 ppb	1.7 ppb	1/10,000,000	1/10,000,000	7
etc.	17 ppb	1/100,000,000	1/1,000,000	8
	170 ppb	etc.	1/100,000	9
	1700 ppb		1/10,000	10
	17 ppm		1/1,000	11
	170 ppm		1/100	12
	1700 ppm		1/10	13
	1.7 %		1	14
	17. %		10	15
				etc.

You will observe that to avoid using long numbers in the first column, the author has jumped from ppb to ppm to %. Chemists have a better way of expressing such long numbers. All numbers can be expressed in powers of 10.

$100 = 10 \times 10 = 10^2$

$1{,}000 = 10 \times 10 \times 10 = 10^3$ etc.

By agreement $10^0 = 1$

Mathematicians have worked out the equivalents of fractional powers of 10. i.e. $10^{1.5}$ etc. and these are listed in logarithm tables.

Thus chemists define pH as a short form, taken from the power of 10 which appears in the fraction under concentration of H^+. To convert fractional pH numbers i.e. 7.57 etc. back to concentrations, when necessary, the chemist uses "log" tables.

When using pH units though, even chemists sometimes forget that: 1 pH unit equals a <u>tenfold</u> change in <u>hydrogen</u> ion concentration.

0.1 pH unit equals a <u>20%</u> change.

Note that the range is not necessarily 0 - 14.
Acids as strong as - 0.3 pH and alkalis of 14.5 pH are known.

The relation between pH and "acidity" or "alkalinity" can best be illustrated by the analogy of tanks of water.

pH measures degree or intensity of acidity or alkalinity

"Acidity" or "Alkalinity" analyses determine amounts.

Thus two tanks of similar depth but different sizes give the same pressure (intensity) at the outlet, but hold entirely different amounts of water. Similarly, two different solutions at the same pH can hold entirely different amounts of acidity (or alkalinity). This is dependent on their "buffering power". In water this is provided mainly by the bicarbonate ion HCO_3'.

(strong acid) $H^+ + HCO_3' \dashrightarrow H_2CO_3$ (weak acid)

(this can break down further into $H_2O + CO_2$ which escapes.)

(strong base) $OH' + HCO_3' \dashrightarrow H_2$) $+ CO_3''$ (weak base)

COAGULATION AND SEDIMENTATION OF WATER

by

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An Address To
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COAGULATION AND SEDIMENTATION OF WATER

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Many of our waters are unfit for domestic use due to the presence of colour, turbidity, bacteria, and other organisms. In a few cases, sedimentation will settle out the suspended material and produce a satisfactory water. In most cases, coagulation is necessary to obtain satisfactory settling.

COAGULATION

Coagulation is brought about by the addition of chemicals, that in very dilute solution form gelatinous precipitates that have the ability to gather together suspended material and form a floc. For good coagulation it is essential that the coagulant be dispersed throughout the water as rapidly as possible. This may be done either by mechanical agitation or by introducing the chemical into the suction side of a pump. If the best efficiency is to be obtained it is necessary to follow the rapid mix with flocculation. This consists of a period of slow mixing, and in this case the velocity of the water should be just great enough to maintain the floc in suspension. A rolling movement in the water will assist the floc to grow and pick up the suspended material. It is essential that once the floc has formed turbulence and periods of high velocity be kept to a minimum until settling is complete, otherwise the floc may be dispersed and all the benefits of flocculation lost.

COAGULANTS

Salts of aluminum and iron are the coagulants commonly used in water treatment. Filter alum or aluminum sulphate is the chemical usually used. Aluminum chloride, sodium aluminate, ferric sulphate, ferrous sulphate and ferric chloride all have a more limited use. The sulphates are better coagulants than the chlorides, but the chlorides may be used for reason such as cost or because they are more available. In general, aluminum salts have some advantages for coagulation in the lower range of pH and iron salts in the high pH range. There are many variables affecting the use of coagulants, such as, pH, dissolved solids, alkalinity, acidity, temperature, turbulence, etc. It is possible to change some of these variables to obtain optimum conditions others have been set by plant design or by nature and have to be accepted.

ALUM

In normal water works operation alum coagulates in a pH range of 5.5 - 7.5. In this range, the alum is only partially hydrolized and precipitates as a hydrated sulphate that forms a dense floc that settles well. In a water softening plant the reaction occurs in a pH range of 10-12, in this case, hydrolysis is almost complete and floc formed is lighter and consists of almost pure aluminum hydroxide. If the pH is raised beyond 12, aluminum hydroxide goes back into solution.

When water contains high dissolved solids it is usually possible to get satisfactory coagulation over a wide range of pH. In the case of our northern waters that are highly coloured and have a very low dissolved solids content, it is often impossible to obtain a good floc

with alum alone. In some cases, it is necessary to adjust pH very closely with sulphuric acid. In other cases where alkalinity is low, it is necessary to increase the alkalinity by the addition of soda ash or lime. Lime is the more economical chemical to use but in some cases lime will not produce a floc and it is necessary to use soda ash. Sodium aluminate can also be used to raise the alkalinity and in some cases a combination of alum and sodium aluminate gives the best results.

In wintertime, low temperatures slow up rate of reaction and at 32°F. it is often impossible to produce a floc with alum alone. The best answer in this case is to use a coagulant aid, and activated silica has proved very effective at low temperatures.

If coagulation with alum results in an aggressive water, it is preferable that pH correction take place after filtration. When pH is corrected before or during coagulation, it invariably slows the rate of reaction and is also more costly, as the higher pH results in a greater hydrolysis of the alum and requires more alkali to neutralize the liberated acid.

SODIUM ALUMINATE

This chemical is more costly than alum but has some decided advantages where coagulation takes place in the pH range of 10 - 12, such as in water softening plants. When alum is used in a softening plant, it is necessary to add additional chemcials to react with the sulphuric acid that is set free, but when sodium aluminate is used there is an alkali set free that takes part in the softening reaction and reduces the amount of soda ash required.

As mentioned previously, sodium aluminate is used along with alum in treating soft waters. There is one point to remember when these two coagulants are used together, that they have to be fed separately and the order in which they are added often makes a marked difference in the results obtained. When powdered alum and sodium aluminate are mixed dry they form a sticky mass that will not dissolve and has to be thrown out.

New forms of sodium aluminate are now on the market, that have a lower alkali content than those originally supplied. This type of coagulant has been used with some success, but they usually react in a pH range where coagulation is slow and not too efficient. They have one advantage that the finished water doesn't need pH adjustment to prevent corrosion.

FERRIC SULPHATE

Ferric sulphate is a good coagulant and could be used in most cases in place of alum. It has some advantages in that it reacts over a wider pH range and produces a heavier floc. It also has some disadvantages, in that it is very difficult to put into solution and if coagulation is not complete any iron left in solution will cause staining. It is also more costly than alum in most areas.

FERROUS SULPHATE OR COPPER

This chemical is easier to put into solution than ferric sulphate, but it requires to be oxidized when it is used or there will be the problem of residual iron in solution to cause staining.

Oxidation, however, is not a great problem as dissolved oxygen in the water will oxidize it quite rapidly or it can be done by chlorination. After oxidation its properties will be similar to ferric sulphate.

COAGULANT AIDS

With some waters and especially under certain conditions such as low temperature, it is impossible to form a satisfactory floc with coagulants alone. It is then necessary to turn to other chemicals that are known as coagulant aids. There are a number of these to choose from, such as, activated silica, sodium aluminate, polyelectrolytes and certain clays.

ACTIVATED SILICA

This coagulant aid is probably the one most used at the present time. In many cases, activated silica makes a most remarkable change in the coagulation and flocculation processes. It widens the useful pH range, forms a floc faster, produces a denser, more stable floc that settles faster, gives better clarification, uses less coagulant for turbidity, gives longer filter runs, and is effective right down to the freezing point. Unfortunately, activated silica does not always produce all these desirable improvements and occasionally produces negative results.

The difficulties with it is that it has to be activated and if a batch process is used, large tanks are necessary as it has to be stored as a dilute solution. If a continuous activator is used it has to be controlled carefully. If a mistake is made, the result is usually a large tank of silica gel that has to be disposed of.

There are many chemicals that can be used to activate the sodium silicate and it is usually possible to select one that will serve a double purpose. For example, if chlorination is being used in the plant it is natural to use ammonium sulphate. In a water softening plant, sodium bicarbonate would be a natural choice. In most plants, chlorine could be used to advantage. There are also many other chemicals to choose from, such as, the strong acids, acid forming chemicals such as the bisulphates, sulphur dioxide and carbon dioxide.

CLAYS

Bentonite and other clays are often useful in coagulating clear coloured waters in which there is no suspended material to act as nuclei for the formation of floc. In this case, the clay acts as nuclei and also builds up a denser floc that has better settling properties.

POLYELECTROLYTES

There is quite a large number of compounds being sold as coagulant aids under the name of polyelectrolytes. Included in this group are starches, esters of cellulose, polymers and gums. In general, they produce results similar to activated silica and in some specific cases have been superior. However, the finding of our laboratory, to date, is that activated silica is still the best all around coagulation aid that we have tested. In comparing costs, silica also has an advantage.

SODIUM ALUMINATE

This chemical is not as spectacular as activated silica but is certainly worth considering when satisfactory coagulation cannot be obtained with alum. It has the advantage that it doesn't have to be activated and can be fed from most types of feeders. It is necessary to use certain precautions as mentioned earlier.

JAR TESTS

With all the information we have and all the work that has been done in the past, it is still impossible to say which coagulant will be best for a given water. There is still only one way to find out and that is to carry out tests with a jar tester.

A jar tester is simply a multiple stirring device that allows us to (a) compare coagulants under identical conditions, (b) determine optimum dosage for any coagulant, (c) determine the order of adding chemicals to give the best results, (d) decide the kind of mixing that will produce the best floc, (e) determine the length of time to form a floc, (f) estimate the rate of settling to be expected from the floc formed.

In water works where the condition of the raw water changes frequently, a jar tester is a "must" if efficient use of coagulants is to be obtained.

The standard jar test uses a two minute rapid mix followed by a thirty minute slow mix for flocculation. This gives good results

for comparing water and coagulants but is not too satisfactory for plant operation. It is necessary to duplicate the rate of mixing and times used in the plant, otherwise the results obtained might be misleading.

SEDIMENTATION

Sedimentation is the settling out of suspended material in a liquid due to the force of gravity. There are several factors that influence the rate of settling. Particles tend to settle at a rate in proportion to their diameter. However, when particles become very fine, the influence of the electric charge carried by the particles is noted and when the force of this charge is greater than the force of gravity the particles are dispersed and will not settle. This is known as a colloidal suspension. Specific gravity of the solids also effect the rate of settling, but as the specific gravity of most natural turbidities is fairly constant, it is not necessary to consider it. However, the density of a floc may vary considerably depending on coagulant used, pH and other factors, and in the settling of coagulated solids the density of the floc can be important. Jar tests will often show that a small dense floc settles much more rapidly than a large fluffy floc. Temperature is also an important factor in settling due to its effect on the viscosity of water.

The purpose of sedimentation is to remove as much of the suspended solids as possible in the time available. To do this, it is necessary to produce a sedimentation basin with the lowest possible rate of flow and a minimum of turbulence.

In designing settling basins, some consideration should be given to sludge removal. Where turbidity is low and coagulant dosage small, occasional dewatering and cleaning of a tank may be satisfactory. Where turbidities are high and high coagulant dosage is required, much of the effective settling time can be lost to sludge storage if some means of sludge removal is not supplied.

PROBLEMS IN FILTRATION

by

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PROBLEMS IN FILTRATION

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Satisfactory operation of rapid sand filters is dependent upon several factors. Inadequate attention to any one of these factors will cause inefficient operation. The efficiency with which the process functions is determined by the design features of the filter, the quality of the pretreated water, the rate of filtration, and the maintenance which the filter receives.

There are two main divisions of treatment in any filter plant. These are (1) chemical and biological raw water conditioning in preparation for filtration and (2) the mechanical filtering of the water. The nature and quality of pretreatment processes have a major influence on filter behaviour. Pretreatment is as necessary for the proper operation of a filter plant as the provision of blocking to a football team's running attack. Many of the problems that materialize in the field of filtration are therefore concerned with coagulation, sedimentation and pretreatment of water before filtration, which have already been considered. Problems that are now to be discussed deal with the second part of the treatment, the actual filtration of the water.

Filtration is a purely mechanical treatment of the water. No biological or chemical reaction is necessary for satisfactory performance or efficiency. It consists of passing a suitably pretreated water through a bed of sand or anthrafilt supported upon gravel. Particle size of the filter media, uniformity,

porosity, bed thickness, as well as other factors, affect the filtration rate that may be used effectively. The design of plants must be based on the knowledge relative to conditions that will be met at individual plants. Therefore, there can be wide variation in the actual design of the various components of a filter plant.

There are two major purposes for the provision of filtration at any water works plant, namely (1) the protection of public health and (2) the provision of a water of suitable quality. It is well known that many supplies cannot be made safe with chlorination alone. Therefore, filtration becomes a valuable and necessary adjunct to prepare the water and to assure that the sterilization applied is effective. The public, in addition, expect to be provided a water that is clear and also free from taste, odour and colour. Filtration is the additional treatment that achieves that goal in its two pronged attack by raw water conditioning and its mechanical filtering action. Most surface supplies require filtration on occasion, some at all times, to assure that public health is protected and that a good, clean potable water is provided.

Filters consist of a bed of sand, or anthrafilt, or a combination of the two mediums supported on a bed of gravel. The usual depth of sand is 27" to 30"; of gravel, 18". The effective size of the sand generally used in a rapid sand filter varies from 0.45 to 0.55 of a millimeter. Anthrafilt, a filter medium processed from selected anthracite has a coarser effective size. There has been a trend toward the use of this coarser material in recent years. This has resulted from the many improvements which have been made in

plant design and in methods of preparing the applied water. However, there are many instances where the solid particles in the applied settled water are very small and where sand continues to be the more effective medium. Carefully graded layers of gravel are used beneath the sand for two major purposes, (1) to disperse the back wash water evenly throughout the filter, and (2) for supporting the sand and preventing it from getting into the underdrains.

In addition to the gravel, an underdrainage system is provided in each filter which is capable of not only uniformly collecting the filtered water, but also of uniformly distributing the relatively large flow of water, when the filter is being cleaned or back washed. The most common arrangement, and one that is still being used, is the header and lateral system. Other drainage systems have been developed in recent years to provide better hydraulic characteristics. Most recent installations are of this type and many include a false bottom, which eliminates the need for deep layers of gravel and also provides a more uniform filtration and distribution of water.

The mechanical control of the filter is provided by a rate controller. The purpose of this control is to keep the filter rate constant. If it were not for the rate controller, the filter would operate at a high rate at the beginning of the run and would gradually drop off as the loss of head increased. The rate controller avoids the necessity for frequent adjustment that is required, if the unit is manually operated. Loss of head gauges

of some kind are also necessary, so that the operator may ascertain the condition of the filter at any time, so as to determine when back washing is required. Other necessary equipment of a filter are the facilities required for surface washing, the wash water troughs to take the high flows of the back-washing operation and direct it to waste, the pneumatic or hydraulic controls for valves, and the control table. All parts of the filter, the medium, the underdrains, the troughs and the controls are important in the proper operation of the filters, and in relation to the problems that arise from time to time.

There are many problems that may cause concern from time to time. Major difficulties are occasioned by faulty operation, dirty filters, micro-organisms, algae, improper flocculation, peculiar turbidity conditions, mud balls, cracks, poor selection of medium, shifting of gravel, poor back-washing, air binding, break-throughs, and other conditions. Such problems will be considered in turn in this lecture. Comments will be made, as to their cause, the methods that can be employed to avoid them in the first instance, and the operation suggested to provide correction, if it is required.

FAULTY OPERATION

Faulty operation is the cause of many of the problems that are created in any water works plant, and result in the production of a product that does not meet recognized standards. Care must be exercised that the quality and quantity of the water being applied to the filters are within proper limits. No longer is it considered

proper operation to apply dirty water to filters, as many installations function poorly when heavy loads are placed on them. There must not be an indiscriminate increase in filter rates in an old plant. There has been a tendency to overload filter units, in recent years, because of ever increasing demands. This overlooks the fact that proper design for such an increase requires different raw water conditioning, hydraulic capacities, and coarser mediums. An increase in rates, except for limited periods, is unwarranted in an old plant, unless it is accompanied by improvements in pretreatment, and more ample filter and piping facilities.

The correct method for avoiding difficulty, due to faulty operation, is to provide pretreatment that will ensure that the quality of the water reaching the filters is satisfactory. In many instances, water reaching filters in properly operated plants is better than the quality of the water that was turned out from plants years ago. Filters are needed to eliminate the fine turbidity that still remains in suspension, and to provide final clarification, so necessary for post sterilization treatment. They should be operated at their designed rate, or even lower at periods of difficult water. Any increase in filter rates should be made only under satisfactory pretreatment conditions, and then only on a limited basis.

The corrective measure that must be employed in this instance is a reversion to proper operation methods. If the plant has been run in an improper way over a long period of time, it is quite possible that correction will not be achieved without alteration

in facilities to provide more adequate capacity, and even replacement of the filter medium, to return the unit itself to a clean condition. The basic principle, therefore, is to operate properly with a clean filter, and not to overload the filter with high rates of application.

ALGAE AND MICRO-ORGANISMS

Algae, and in some cases plankton, not removed in advance of filtration, will often clog filters quickly. This problem is becoming more severe as sanitary wastes, fertilizers, and other organic discharges increase growths of algae in surface waters to a prolific degree. Filter runs as low as three or four hours become common under such conditions, taxing both the capacity of the plant and personnel to produce even ordinary demands for water.

This is a problem that, in many instances, must be met at the water works plant. The advent of the micro-strainer has been a major factor in the correction of this adverse condition, particularly in the elimination of algae. Proper use of copper sulphate to kill algae and other micro-organisms can also be used to advantage. Floating algae can be removed through overflows from the settling tank, located just above the normal water level, by retarding the flow through this section of the plant. While this problem is more common, it can be said that the methods that can be employed against it are now becoming more effective.

IMPROPER FLOCCULATION

It is essential that the amount of coagulant that is added to the raw water in the mixing chambers, the degree of agitation of the chemical and the water, and the period of mixing, is important, if one is to obtain proper flocculation, prior to settling. This is one of the steps in the treatment of water that can be the subject for daily research, in order to determine the most economical dosage that will produce the best floc for the condition that is existing at the time. The quality of the suspended matter is very important. It is possible to filter the water at a high rate, if the floc in the settled water is tough, but the opposite may be true, if the floc is loosely bound together.

The best corrective measure for improper flocculation is continual research. The use of the jar test for making determinations to ascertain the correct dosage and experimentation with alum, activated silica, ferric chloride, ferric sulphate, and coagulant aids to determine the best chemical to use, is a source of study that can be of considerable interest and value, in any water works plant.

PECULIAR TURBIDITY CONDITIONS

The concentration and quality of the suspended material are important, as they often cause concern at a filtration plant. The higher the amount of suspended matter in the water, the greater is the danger of a break through the filter. There are occasions, particularly with finer turbidity, that double filtration of a

portion of the water being treated may be required. Heavy wind agitation of water and spring run-off in intake areas may cause adverse turbidity conditions that are difficult to combat, without considerable adjustment of the raw water conditioning of the water.

Pretreatment of water is important, in overcoming difficulties that are experienced, because of peculiar turbidity conditions. The use of activated silica, and special coagulant aids, have been found invaluable in toughening up flocs, so that turbidity can be adequately settled before the water reaches the filter. The use of sand, as a media, is more effective in a plant that has difficulty from this standpoint, as the larger the openings between the media, the more chance turbid water will pass through.

MUD BALLS

Mud balls are a condition that has caused concern in many filter plants. They are caused by compacted, flocculated material that mixes with filter media, and gradually grows in size and sinks through the media to the gravel. As mud balls grow in size, they cause difficulties in back-washing operation and displacement of the gravel. Mud balls can eventually extend through the entire filter, causing markedly reduced capacity, and other adverse conditions.

The advent of the surface wash and better back-washing has brought a reduction in mud ball conditions in filters. If they are to be avoided entirely, routine inspection of the filters should be standard practice, to determine if they are developing.

Sampling of the media from the top 6 inches of the bed, and passing it through a fine sieve, under water, will show the presence of mud ball material. Proper pretreatment, regular and consistent back-washing, and surface washing operations and sampling, to determine the presence of mud balls, are steps that can be taken to prevent their formation. Anthrafilt, being lighter than sand, is more prone to mud ball formation than sand.

Filters will, on occasion, crack, when mud ball conditions become severe. Compaction of the sand, or anthrafilt, takes place during the filter run, and the media sinks, causing cracks in the bed and along the sides, resulting in unsatisfactory filtration.

This is a severe condition, and can only be rectified by removal, cleansing, and replacement of the sand and gravel. When the media is replaced, the condition will again return, if every effort is not made to prevent formation of mud balls by proper operation and supervision.

POOR SELECTION OF FILTER MEDIA

The choice of sand, anthrafilt, and gravel used in filters may cause trouble in operation. The selection of media should be based on an evaluation of the conditions that must be met, and the degree of pretreatment that must be provided. If too fine a media is selected, it will curtail the flow through the filter; if it is too coarse, it will permit fine turbidities to pass through. Proper selection and placing of gravel is also essential, if

back-washing is to be carried out satisfactorily. Loss of head development occurs more quickly in the filters with the finer media. On the other hand, filters with coarser media are often operated for long periods between back-wash periods. This is a practice that, on occasion, results in the development of a bad mud ball condition.

SHIFTING OF GRAVEL

Trouble is caused in filtration by the shifting of gravel in the bed. There is always a certain amount of shifting of gravel in any filter, but it is generally not a serious condition. However, faulty underdrainage systems, and incorrect back-washing, may cause gravel to rise and even go through the sand. When this occurs, it affects filtration, and also permits the sand to sink into the underdrainage system.

Routine inspection should be a standard practice in any filter plant, to determine if this condition is developing. The use of a small, wooden probing rod, during back-wash periods, will show the location of the gravel. It can then be readily determined, if the gravel is shifting. Corrective measures can be employed, by varying the back-wash operation, to prevent or control the shift. In severe cases, the media has to be removed, and the under drains examined and improved before the media is again installed.

IMPROPER BACK-WASHING

The back-washing of the filter may cause difficulty, if it is carried out improperly. The nature of the impurities in the water, and the chemicals that were used in coagulation, are important

factors in determining the length of the back-wash period. If the water has contained a high turbidity that was not properly pretreated, it may require a longer period of back-washing than usual, to remove the turbidity. The type of media in the filter must also be considered in the back-washing operation. Anthrafilt requires a much lower rate of back-wash, because of its lower specific gravity. More back-wash water must also be provided in winter, than in summer, to achieve the same expansion of the sand, or anthrafilt. Wash water troughs must also be located sufficiently high, so that the sand can be expanded about fifty percent, without danger of the media overflowing into the troughs. The underdrainage system and the gravel are also important factors in providing a proper back-wash rate.

In order to carry out back-washing properly, adjustment must be made for the media, the temperature of the water, the condition of the filters, and the design of the underdrains, the wash-water troughs, and the surface wash arrangements. Various alterations of the back-washing rates between ten and twenty U.S. gallons per minute, per sq. ft., must be tried to determine the best rate with sand, with rates of approximately one half that amount for anthrafilt. The filters should be tested with the probing rod, during back-washing, and a close watch should be made for high concentrations reaching the surface at spots in the filter bed, to determine if cracks, or other break throughs, are materializing.

AIR BINDING

Air binding is a condition that occurs in some filters, particularly in the winter when the water being treated is cold. It is caused by the creation of the presence of air in the lower part of the sand, or anthrafilt bed, with a resulting marked reduction in the filtration rate. It is likely to occur in a filter when negative head exists in a filter, or when the loss of head, because of friction of the filtering water, at some point in the bed, is greater than the vertical distance from the water surface to that point. The condition can be accentuated, if the influent water level of the filter is lowered.

This is a condition that can be avoided, if the filters are operated so that the loss of head in the filter is kept low, and if back-washing is carried out regularly. The head of water above the sand should also be held as high as possible, but the basic way to avoid air binding is more frequent back-washing.

On occasion, when air binding has developed, the air can sometimes be expelled by bumping the filter, or a short application of back-wash water at repeated intervals. This may have adverse effect on the gravel strata and, therefore, is not to be considered as an alternative to the proper operation of limiting operation rates and lengths of runs.

BREAKTHROUGHS IN FILTERS

Filter breakthroughs can adversely affect the filtered water quality. There is always a certain amount of breakthrough of suspended matter, at the start, of any filter run. At one time it was common practice to waste some water at the start of any filter run, but in most instances that method is no longer employed. As a result, some floc may be carried into the filtered water. This will persist longer when coarser media material is used.

There can also be breakthroughs toward the end of filter runs, if the floc is not sufficiently strong to achieve proper sedimentation. This condition can be ascertained by spot-checking of filters, by employing turbidimeters, or by watching the loss of head gauges closely. As breakthroughs become a hazard, the loss of head will develop more on a straight line basis toward the end of the run. Normally, loss of head should develop more quickly at the end of the run. If the loss of head should drop toward the end of the run, it is an indication of the probability that a breakthrough is occurring. The basic corrective measure for breakthroughs is earlier back-washing, in conjunction with adequate surface washing.

OVERLOADING OF FILTERS

One of the major problems, in connection with filter plants, is overloading. This has been accentuated in recent years, as water works capacities have endeavoured to cope with ever increasing demands. Operators have tried to put more and more water

through the filters at peak demand periods, if the piping and media will permit such an increase. As a result, all the various problems that occur in filters become more prevalent. In time, such a practice can produce breakthroughs, air binding, mud balls, and cracks. It is essential, therefore, that the correct capacity of the filters be known, and that the plant be operated on that basis.

It is also good practice to run all filters at the lowest possible rate, rather than to turn them on and off, to govern plant production. If that policy is followed, the water quality and the safety factor will improve. It must be remembered that, in order to use the lower filtration rate, that the terminal head loss should be proportioned to the filtration rate being used.

SUMMARY

This lecture has been prepared for this basic course to discuss, in a general way, some of the major problems that occur in filtration plants. In later courses, factors involved in specific problems, such as mud balls, improper back-washing, air binding, and breakthroughs, will be covered in more detail. Filtration is one of the two major treatments in any water works plant, and it will, therefore, be covered thoroughly.

The following principles are laid down, as indicated previously. (a) There are two main parts to the treatment in any filter plant, (1) raw water conditioning, and (2) mechanical filtration of the water. Both should be carried out properly, if the filtered water is to be of good quality. (b) There are two

major purposes for the provision of filtration, (1) protection of public health, and (2) the provision of water of a suitable quality. (c) Filters are hampered in their aim of turning out a water of the desired turbidity, by a variety of conditions, such as poor raw water conditioning, mud balls, breakthroughs, air binding, inadequate wash water distribution, and other factors. (d) The basic principles to good operation are (1) good raw water conditioning, (2) frequent back-washing, according to recognized standards, (3) regular checking of the sand, anthrafilt and gravel, (4) turbidity and other tests, to determine the quality of the water, and (5) avoidance of over-loading of the filters.

RECOMMENDED PROCEDURES IN THE USE OF CHLORINE

by

K. H. Sharpe

Supervisor - Water Works - OWRC

An Address To
The Ontario Water Resources Commission
Basic Water Works Course
Toronto, Ontario
December 6, 1960

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OBJECT

The chlorination of public water supplies represents the most important process used in the production of water of a safe, sanitary quality. It is only as effective as the control that is exercised in ensuring that all of the supply continuously receives chlorine in an amount proportional to the flow, that will produce effective disinfection. Disinfection refers to the reduction of the bacterial population to a safe level, as contrasted to sterilization, which refers to the total destruction of the bacterial population.

The object of disinfection is to kill disease producing organisms which may have gained entrance into a water supply. The germs involved are primarily those causing intestinal diseases such as typhoid, the paratyphoids, and dysentries; most other harmful bacteria are not considered to be spread by impure waters. Invariably, in surface waters are also present typical soil and water organisms regarded as harmless.

Other disinfectants have been tried and used such as ozonization, ultra-violet radiation, bromides, silver, etc., but with few exceptions, chlorine is the main chemical employed. Chlorination is synonymous with the disinfection of water, and is used in the form of a gas or one of several compounds such

as chloride of lime, sodium and calcium hypochlorites.

FORMS OF CHLORINATION

GAS CHLORINATION

Under conditions of normal temperature and pressure, chlorine exists as a gas. However, it can be easily compressed to a point where it liquifies. This property is utilized to supply the chemical in steel cylinders of 150 lbs. and ton containers or 30 ton tank cars.

Essentially, chlorinators consist of various combinations of pressure reducing valves actuated by mechanical diaphragms, or hydraulically operated floats, orifices or other types of meters for measuring the rate of flow of the chlorine gas after it has been reduced to a uniformly low pressure, and devices for making an aqueous solution of the gas and injecting this solution into the water to be treated.

For proper operation, chlorination equipment requires some care and attention. Manufacturers' recommendations and instructions should be made available to the operator of the equipment and should be followed. It is prudent for the operator in turn to become thoroughly familiar with the equipment so that he may become competent to make the necessary adjustments and minor repairs.

Chlorine leaks may be detected by holding an open bottle of ammonia near the suspected points. If chlorine is escaping, the whitish fumes of ammonium chloride will be formed and observed. As chlorine gas is an irritant, special care should be taken in order

that none of the gas is inhaled. Gas masks should be stored in a readily accessible place, away from the chlorinator or chlorinator room, so that they are available for immediate use when needed. It is needless to say that all chlorine leaks should be repaired as soon as possible, if there is to be no personal injury or damage to valuable equipment.

Chlorine cylinders should be placed on accurate scales in order that the chlorine can be weighed and the quantity used each day can be determined and recorded. These scales should be so located that the chlorine cylinders will be cooler than the chlorinators, in order that the gaseous chlorine, flowing from the cylinders to the chlorinator, will not condense. In general, about 35 to 40 lbs. can be obtained from each 150 lb. cylinder when ordinary room temperature prevails. If more than 35 lbs. per day is required, then several cylinders can be connected together to obtain the desired quantity.

Duplicate chlorinators should be provided to ensure continuous chlorination under all operating conditions which, of course, includes maintenance, interruptions and breakdowns. Spare parts such as meter tubes, control valves, gaskets etc., should be kept on hand so that repairs can be made readily.

HYPOCHLORINATION

We have already indicated that other compounds of chlorine such as sodium or calcium hypochlorite are used. Usually, these

hypochlorites are added to the water to be treated in solution form.

Sodium hypochlorite solution is available under various trade names. These solutions vary in strength, but usually have 12 per cent available chlorine by weight and are reasonably stable when stored in cool, dark places.

Calcium hypochlorite, also known as chloride of lime, is also used at times. As this compound is relatively unstable, it should be purchased in small quantities. The commercial products ordinarily contain 25 to 37 per cent available chlorine by weight. However, there are several commercial compounds containing 65 to 75 per cent available chlorine by weight. These latter compounds are more stable, but more expensive.

Hypochlorite solutions, as used in water works practice, are diluted to a solution strength of between 0.5 to 1 per cent by weight. In preparing these solutions, the chlorine content of the concentrated solution must be taken into account. As an example, let us calculate how many pounds of chloride of lime, with an available chlorine content of 33 per cent, need be added to 30 gallons of water to make a 1 per cent solution of chlorine.

The weight of water = 30 x 10 = 300 lbs

The weight of chloride of lime = X say

Hence, the weight of chlorine = 33% of X = 0.33X

Therefore, for a solution containing 1% of weight

$$\frac{0.33X}{300} = 1\% \text{ or } 0.01$$

i.e. 33X = 300 and X = 9.1 lbs

or

As an example, if 30 gallons of a 1% solution is to be prepared using chloride of lime with 33% available chlorine, the weight of chloride of lime that is needed would be

$$\frac{30 \times 10 \times 0.01}{0.33} = 9.1 \text{ lbs.}$$

The usual type of equipment that is used is essentially a diaphragm solution pump. Manually controlled equipment is satisfactory when the rate of flow is uniform, such as a pumped supply. When the rate of flow is not uniform, it is then essential that a proportional feed hypochlorinator be used, generally of the meter-paced type. In all cases, the capacity of the chlorinator should be sufficient to meet the demand and still have excess capacity for emergencies.

CHLORINE RESIDUAL

Chlorine reacts so rapidly with most oxidizing material present in natural waters that the amount applied is swiftly depleted. Most bacteria will be killed in the first two minuted of contact time with the chlorine.

It is the practice in Ontario to maintain a control concentration of 0.2 to 0.3 p.p.m. after 15 minutes application to the water. This quantity is known as the chlorine residual; it represents the chlorine remaining after the fifteen-minute reaction interval and still available to combat some of the more resistant organisms and to safeguard against later pollution. The chlorine actually absorbed is termed the chlorine demand;

its value is obtained by subtracting the chlorine residual from the original chlorine dosage. The chlorine feed equipment is adjusted on this basis. An increased residual should be carried if ammonia or interferring substances are present, or if the bacteriological findings warrant.

The details of the residual test will be demonstrated in the laboratory. The procedure that is followed is to add a small amount of orothotolidine solution to the water sample. Any residual chlorine produces a yellow coloration, which is compared against standard colors to determine its concentration.

FACTORS INFLUENCING DISINFECTION

There are three main factors that influence the desired chlorine residual. These are:

1. Time - Concentration -- These two related factors take into consideration the period of the reaction time that is available for disinfection, and the quantity and kind of chlorine residual. Combined available chlorine has a slower reaction time than free chlorine. The former is usually satisfactory under Ontario requirements of a minimum of 15 minutes contact time. Free available chlorine, on the other hand, is used when special raw water conditions are encountered as a control on the demand, and to ensure that more chlorine is available to meet wider fluctuations in demand, such as may occur with the presence of phenols.

2. Temperature -- The temperature of the water markedly affects the disinfection action of residual available chlorine. In order

to obtain the same bacterial kill with a temperature of 40°F., as compared to the temperature of 70°F., all other factors being equal, the concentration of the combined residual must be more than double that of free residual.

3. pH -- The pH of the water affects the disinfecting action of chlorine, particularly combined available chlorine residual. At pH 6.5 and a temperature of 70°F., 0.3 p.p.m. of combined residual causes a 100 per cent bacterial kill. With the same temperature, at a pH of 7.0, the combined residual must be increased to accomplish the same degree of bacterial kill.

STORAGE OF CHLORINE AND OTHER WATER WORKS CHEMICALS

by

W. Steggles

Engineer - Surface Water - OWRC

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A major objective in the chemical treatment of water is the careful regulation and control of the application of chemicals to prevent under-treatment or over-treatment. Achievement of this objective requires proper and adequate handling and storage of water works chemicals. This lecture will be concerned with both handling and storage of chemicals since these topics are inextricably related.

A multitude of chemicals are available for water treatment applications depending of course upon the purpose or desired results of treatment. Disinfection of a water supply will require the use of chlorine, chlorine dioxide or some other disinfectant; coagulation of water may involve the use of aluminum sulphate, sodium aluminate, ferric sulphate, activated silica and lime; water softening will require lime and soda ash possibly; while taste and odour control may use activated carbon, chlorine, chlorine dioxide and other chemicals. Our study will be limited to the handling and storage of chlorine and its related compounds, alum, lime, activated carbon and fluorides. These particular chemicals which represent the gamut of water works chemical treatment usually present the most difficult problems that are encountered in chemical handling at water treatment works.

Appreciation of the reasons why specific chemicals are handled in certain ways requires that operating personnel become intimately acquainted with the essential physical and chemical characteristics of the chemicals to be handled.

> ILLUSTRATE KAY · OVRN

SIGNIFICANT CHARACTERISTICS OF THESE CHEMICALS

1. Chlorine

Chlorine gas has replaced many chlorine compounds as a more economic and effective means of water disinfection. Its availability in steel cylinders that may be readily handled has made the purchase of chlorine gas more attractive. Hypochlorites are used for particular situations such as emergency applications and in small water works systems.

TABLE 1 (a) Gas and Hypochlorites

CHARACTERISTIC	CHLORINE GAS	CALCIUM HYPOCHLORITE	SODIUM HYPOCHLORITE
Chemical Name of Formula	Chlorine Cl_2	Calcium Hypochlorite $Ca(OCl)_2.4H_2O$	Sodium Hypochlorite NaOCl
Common or Trade Name	Chlorine gas Liquid chlorine	"HTH", "Perchloron" "Pittchlor"	Sodium Hypochlorite
Physical (available forms)			
-state	liquified gas under pressure	solid granule powder	liquid
- colour	yellow green gas	white	clear, light yellow
- odour	sharp, pungent	slightly chlorinous	chlorinous
Boiling Point ^oF.	-29.29 (easily condensed to a liquid)	-	-
Weight with respect to air	2½ times heavier	-	-
Reaction with water	- produces solution of hydrochloric with hypochlorous acids - readily soluble	same as Cl_2 gas readily soluble	completely miscible in water
Corrosive qualities	when dry no reaction with metal when wet reacts with most metals	corrosive in solution	corrosive nature
Stability	liquid vaporizes to gas readily at normal temp. and pressure	fairly stable	deteriorates more rapidly than calcium hypochlorite
Shipping Containers	100, 150 # cylinders 1 ton tanks 16,30 ton tank cars	5# cons; 100-, 300- 800# drums	5-,13-gal. carboys 1300-2000 gal. tank trucks
Commercial Strength (Available chlorine)	99.8% Cl_2	70%	12-15%

~~TABLE 1~~ (b) Bleaching Powder (Chloride of Lime)

These powders contain about 25-35 per cent available chlorine. The remainder is slaked lime. Loss of strength, as available chlorine, is rapid once the container is opened and the contents exposed to air. Chloride of lime dissolves with difficulty and leaves a slurry of slaked lime in the pot.

2. Alum, Lime and Activated Carbon
These 3 chemicals are grouped together at this point for convenience.

TABLE II - Alum, Lime and Activated Carbon

CHARACTERISTICS	ALUM	LIME	ACTIVATED CARBON
Chemical Name and formula	Aluminum sulphate $Al_2(SO_4)_3 . 14H_2O$	Calcium oxide CaO	Activated carbon C
Common or Trade Name	Alum filter, alum sulphate of alumina	burnt lime chemical lime quick lime unslaked lime	"Aqua Nuchar" "Hydrodarco" "Norite"
Physical state (available forms)	Solid - (powder (granule (lump or liquid (syrup)	Solid - lump pebble granule	Solid - granule powder abt. 99% passes #200 mesh sieve
- colour	ivory	white when pure	black
Freezing Point	liquid form as shipped about 10° F.		
Weight per cu.ft.	65 lb. (ground)	lump lime 55 lb. slaked lime 38 lb.	14 lb.
Reaction with water	very soluble syrup or liquid - acid reaction solid - basic as packaged	chem. lime reacts with water to produce slaked lime at ordinary temps. Slaked lime only slightly soluble in water.	insoluble - (used in suspension)
Corrosive Qualities	pH of liquid as shipped - 2.3 pH of 1% solution - 3.4 when dry - not corrosive when wet - very corrosive	not corrosive pH of saturated solution 12.4	-
Stability	Stable	Chemical lime reverts to slaked lime in moist atmosphere	Stable
Shipping Containers	100-200 lb. bags 300-400 lb. barrels bulk carloads	50 lb.bags 100 lb. barrels bulk carloads	bags, bulk
Commercial strength	solid 15-22% Al_2O_3 (aluminum oxide) liquid 8.3% Al_2O_3 equivalent to 48.8% dry aluminum sulphate	75-99% CaO	-

The following comments are made in respect to activated carbon with the knowledge that these characteristics will undoubtedly be included in the lecture on "Taste and Odours" in Water Supplies. It is felt that by describing the phenomenon of "absorption" and the process whereby activated carbon is produced, knowledge of the handling of this material will be enhanced.

The principle of use of activated carbon is the capacity of the chemical to exhibit the property of absorption. This is considered to be the phenomenon of concentrating certain substances, in this case odorous organic compounds at the exposed surfaces of the solid. It is this property which is exhibited not only in the treatment unit, but as well in the storage area at the water works plant. The presence of chlorine in the plant atmosphere as a gas will reduce the absorptive capacity of the carbon since the chlorine itself will be absorbed.

Activated carbon is made by the conversion of the raw material wood to char by carbonization at temperatures below 500°C. The char is then activated by a slow burning operation under closely controlled conditions at temperatures from 800°Cent. upward.

3. Fluorides

It is proposed in this study to ~~steer clear of the~~ controversial aspects of fluoridation and confine both the properties described and the ensueing remarks to those related to the handling and storage of fluorides.

TABLE III - Fluorides

CHARACTERISTICS	SODIUM FLUORIDE	SOD. SILICO FLUORIDE	HYDRO FLUOROSILIC ACID
Chemical Name	as above	as above	as above
Chemical Formula	NaF	Na_2SiF_6	H_2SiF_6
Common Name or Trade Name	fluoride	as above	fluosilicic acid
Physical State (available forms)	Solid - crystalline powder	Solid - powder	liquid
- colour	nile blue or white	nile blue or yellowish white	-
Reaction with water	limited solubility	less soluble than NaF	in solution
Corrosive qualities	pH of 4% solution 6.6 slightly corrosive	pH of 1% solution 3.5 corrosive	corrosive
Stability	storage of large quantities of the solid form tends to result in moisture pick-up and resultant caking.		
Shipping Containers	bags, barrels, fibre drums, kegs	bags, barrels, fibre drums	rubber-lined drums
Commercial Strength	90-95% NaF	99% Na_2SiF_6	about 35%

ILLUSTRATE

It is noted, with respect to the commercial strength of these compounds, that the actual available fluoride amounts to much less than the figure given for Commercial strength. About 40 per cent of the sodium fluroide and about 60 per cent of the sodium solica fluoride is present as available fluroide.

With this background of the significant characteristics of the chemicals under study, attention will now be given to matters of more practical concern to the plant operator.

The following topics will be discussed:

1. Physiological or Health Hazards Involved.
2. In plant handling, including inventory and the efficient transport of these chemicals from receiving to storage and application. The dependable and accurate application of these chemicals will be dealt with by others throughout this course.

1. PHYSIOLOGICAL CONSIDERATIONS

(a) Chlorine as a gas

Liquid chlorine is classified as a non-flammable compressed gas. The gas is extremely irritating to the membranes in the nose, throat and lungs in concentrations greater than 15 p.p.m. Irritation of the skin and eyes results under higher concentrations as well as coughing and difficult breathing. In prolonged exposures to the gas, retching and vomiting following ed by difficult breathing are symptoms. Death can occur from apparent suffocation where breathing difficulties are extreme.

Due to its greater weight than air, chlorine seeks the lowest level in a room. When escaping from a chlorine poisoned atmosphere, it is important to remain above the heavier layers of gas.

First aid procedure which is somewhat beyond this study has been recommended by the Joint Committee Report on the Recommended Procedures in the Use of Chlorine at

Water and Sewage Plants (Journal AWWA, October 1953). Where chlorine gas is used at a plant, it behoves the operator to make himself aware of safety and first aid procedures.

(b) Chlorine in Solution

Whether chlorine be in solution as a dissolved gas or in the form of a dissolved solid, the resultant solution is quite acid and will cause acid burns and irritation of the skin. Where clothing has been splashed by a solution of chlorine, the affected clothing should be removed and the skin washed with copious volumes of water. lab showers

(c) Alum

As a salt of a strong acid, alum in solution forms an acid pH. Contamination of ones clothes or skin should be washed with water as described previously.

(d) Lime and Activated Carbon

Little hazard is involved in handling these chemicals. Fine dust ~~must~~ might cause injury to the eye.

(e) Fluorides

All fluoride compounds are poisonous in all but minute concentrations. When properly handled and stored at a plant fluorides are not dangerous. This statement is supported by the results of investigations performed by medical authorities in the public health field.

Although the details of plant safety are beyond this talk (a separate lecture on "Safety Practices" will be given in the course) it is suggested that these factors are really the most important ones to which consideration should be given.

Closely related to the storage of chlorine is the provision of ample but practical inventories of chlorine. Obviously the size or magnitude of a chlorine inventory will determine the storage requirements for the chemical. It is emphasized that chemicals inventory, especially in the case of chlorine, must be based entirely on the precept that treatment must be continuous for obvious Public Health requirements.

Some factors that bear on the problem of inventory are:

(1) Normal length of time required for delivery from the shipping point to the point of use.

(2) The amount of chlorine used per day during periods of high demand for water.

(3) Emergencies which interrupt chlorine deliveries.

The Joint-Committee on chlorine supply which was established in May 1951 have defined inventory of chlorine as applied to water treatment. These definitions are presented here:

(a) Critical Inventory - The number of unconnected (full) chlorine units or containers equal to the number of units normally connected and in service.

It is stated that a plant should be considered in emergency operation with an inventory of this nature.

(b) Working Inventory - That inventory which represents a reasonably ample supply to assure continuity of treatment. It should approximate:

(1) a duplication of the connected chlorine units (critical inventory); plus

(11) a chlorine reserve equivalent to the length of time required for delivery; plus

(111) a reserve for such occurrences as strikes; transportation interruptions etc. which is equivalent to a 15-day supply. This will vary from plant to plant and must be determined for each individual plant.

(c) Maximum Inventory - That inventory equivalent to a 60-day supply of chlorine at the plant at the normal rate of use. This should only be regarded as a temporary type of inventory since heavy stocks of chlorine tend to tie-up an unnecessary number of containers or cylinders.

ILLUSTRATE FIG. TO

Table IV - Recommended Chlorine Inventories at Water and Sewage Plants * - Joint-Committee Report

Avg. Amount Chlorine Used per Day - lb.	Critical Chlorine Inventory None of Which is in Use †	Working Chlorine Inventory None of Which is in Use	Max. Chlorine Inventory None of Which is in Use
	150-lb. Cylinders		
0.5	1	1	2
2.0	1	1	2
5.0	1	1	3
10.0	1	3	4 ‖
20.0	1	4-5 §	8 ‖
50.0	2-3	8-12 §	20 ‖
100.0	3-5	16-24 §	40 ‖
200.0	6-8	30-47 §	80 ‖
	Ton Containers		
300.0	1	4-6 §	9 ‖ #
500.0	2	8-10 §	15 ‖ #
1,000.0	2-4	12-18 §	30 ‖
2,000.0 ‡	4-6	22-35 §	60 ‖

* 100-lb. cylinders are available. Where they are used instead of the 150-lb cylinders, the net weight of chloride in inventory should substantially agree with that shown in the table.

† This column also represents the number of cylinders or containers usually in service. Local conditions could affect these figures materally. Irrespective of the number of units in service, the principle as expressed in the definition of critical inventory should still apply.

‡ Users of 1 ton or more of chlorine per day should consider the use of single-unit tank cars.

§ The smaller of the two numbers represents the working inventory where deliveries require 2 days. The larger figure represents the working inventory where deliveries take 15 days.

‖ These figures roughly represent 60 days of chlorine inventory.

\# Maximum inventories listed for these categories are for plants receiving chlorine delivery by truck. For plants receiving chlorine delivery by railroad car (fifteen 1-ton containers), the maximum inventories should be 19 and 23 ton containers, respectively, for plants using 300 and 500 lb. per day.

With respect to the uses of chlorine cylinders and ton containers, the following information is included in table form:

Table V - Recommended Uses of Cylinder or Ton Containers

Total Consumption per 24 hr. lb	Max. Rate of Withdrawal per 24 hr. lb	Recommendation	Remarks
100	100	3 cylinders in use (possibly 6 connected)	
100	200	5 cylinders in use (possibly 8 connected)	
200	200	5 cylinders in use (possibly 8-10 connected)	ton containers may be justified *
200	300	ton containers †	1 carload would provide 150 days' storage *
300 or more	300 or more	ton containers †	1 carload would provide 100 days' storage at plants with ~~minimum~~ maximum (300 lb. per day) rate of use

* Delivered by truck; carload lot delivery not usually justified.

† Some changes in this schedule may be required for seasonal users of chlorine.

2. In Plant Handling

Unloading Chemicals

For large plants, adequate provision for handling materials upon arrival is important. Where a railroad siding is available, the transfer of carload shipments either by bulk or package to storage may be facilitated by:-

(i) arrangements of bins whereby bulk shipments can be shovelled directly into them.

(ii) Air conveyors. - P.23 Line Book

(iii) Bucket elevators.

With respect to the regulations and specifications concerning the handling and storage of chlorine, the following regulatory bodies are active:

- In U.S.A. - Interstate Commerce Commission - I.C.C.
- In Canada - Board of Transport Commissioners for Canada - BTCC

The Joint Committee presented some general recommendations in respect to the safer use and handling of chlorine in the report referred to earlier. Some of these are presented here:

(a) Use reliable men in handling chlorine. They should become familiar with BTCC regulations and specifications.

(b) Adequate room ventilation is required both in rooms where chlorine is stored and applied. Where mechanical ventilation is required (where gas tight rooms are employed)

provision must be made to change the air twice every minute.

- Exhaust duct ports should be at floor level, and ducts should terminate in locations where sufficient atmospheric dilution is available for the protection of both personnel and property.
- Air inlets at opposite sides of the room to the exhaust ports.
- Air temperature should not adversely affect the equipment.
- Do not store chlorine containers near elevators, gangways or ventilation systems.

(c) Approved gas-masks should be provided and personnel employed trained in the use and maintenance of the masks.

(d) Testing for chlorine leaks - Use a stick with an end covered with cloth, soak in ammonia water and probe for suggested leaks. A white cloud of ammonium chloride will indicate the presence of chlorine gas.

(e) Due to its corrosive nature when wet, the gas should be handled in materials such as glass, rubber and silver. Caution: Never use water on a leak because the resulting corrosion will make the leak worse. When leaks do arise, correcti e action is required immediately.

(f) Cylinders or containers should be stored at a moderate temperature. Flame or direct heat should never be applied to a container. The fusible plugs will soften at a temperature between 158-165^{o}F., thus releasing the pressure and preventing container rupture in case of fire or other

exposure to high temperature. The container should be kept at a temperature such that the cylinder is not warmer than the application equipment. Never store near turpentine, hydrocarbons or other flammable materials.

(g) Avoid dropping or bumping containers. They should be fastened securely to prevent tipping or rolling. Store cylinders in an upright position and ton containers on their sides above the floor on suitable supports.

(h) Valve protection hoods on containers should always be kept in place except when being emptied. Do not hoist cylinders by the hood.

(i) Keep valves of cylinders and ton containers closed at all times when not in service.

(j) Store full and empty containers in different places to avoid confusion. Tagging might be used.

(k) Use containers in the order in which they are received. Place on a scale when in use so that the operator may know at all times the amount of chlorine in the container.

(l) Use only approved fittings for connecting containers. Never use pipe fittings on chlorine valves.

OTHER CHEMICALS

The powder form of hypochlorites are readily transported and applied within the plant. All hypochlorites when in solution are quite corrosive and handling necessitates the use of corrosion resistant materials. Wood, ceramic, glass, plastic and rubber lined containers and conveyors are used.

The most widely used chemical, in water treatment practice, other than chlorine, alum, is available in both the solid and liquid state. In the past, and to a large extent today, dry crystalline alum has been used as an economical and easily stored coagulant. Only the larger water works plants where alum is used in any quantity can consider the use of liquid alum. These plants are usually located within truck hauling distance of the alum producer.

Alum in solution may exhibit either an acid or alkaline pH, and must be handled accordingly. Corrosion resistant materials such as lead, rubber, plastics and stainless steel are used. Pumps and valves when constructed of nickel base alloy are satisfactory. Storage tanks may be of wood, concrete or steel - all lead lined. Rubber-lined steel and cypress wood tanks, unlined, are in use. Storage tanks in northern climates should be indoors.

Since alum has a moderately high freezing point, care must be taken in unloading bulk carriers where the liquid has cooled. Clogging of piping with crystallized alum will hamper unloading.

Lime is used for water softening either as quicklime or slaked lime. The choice of form depends on economic factors. Hydrated lime is used more generally in smaller plants because it keeps better in storage and does not require slaking equipment. Quicklime, however, costs less per ton of available CaO and therefore is economical for use in large plants.

Lime should be stored in a dust tight area.

The use of powdered activated carbon requires isolated storage and feeding plant to minimize the dirty conditions associated with its handling. Special discharge boxes are used wherein a bag of the material may be opened and emptied to control the spread of the black dust.

The storage location should be selected and designed to avoid the risk of fire. Locations safe from excessive heat, flame or sparks are required. Should the carbon catch fire, extinguish the fire with a fine spray of water or a foam type extinguisher to prevent scattering of the burning carbon dust. Elevation of the bags of carbon on a steel framework that will permit the circulation of air around the bag will reduce any tendency for heat to build-up in the package. This will also protect the material from becoming wet. Wetting will not destroy the activity of carbon, however, trouble may be experienced with feeding due to arching in the hopper.

As indicated earlier, the air should be devoid of chlorine or gas vapors, otherwise the efficiency of absorption will be reduced.

FLUORIDES

The following precautions are given concerning the handling and storage of fluorides.

Attention will only be given to the powdered forms of fluoride.

(i) The operator should follow all instructions as provided by the manufacturer.

(ii) Wear the recommended protective clothing, eg. gloves, masks or other respiratory devices, goggles etc.

(iii) Breathing or swallowing fluoride dust must be avoided.

(iv) Wash thoroughly after handling fluorides and clean up spillage.

The pneumatic emptying and conveying of the powdered fluorides has greatly eliminated the dust hazards. The conveyor nozzle is inserted in the container by this method and the material is drawn upward by the creation of a vacuum. Suitable exhaust fans should be employed to remove any residual dust in the atmosphere.

Due to their corrosive nature to galvanized iron and brass, solutions of either sodium silico fluoride or hydro-fluosilic acid must be handled in corrosion resistant materials such as rubber or plastic, stainless steel, monel metal, porcelain or tar-coated wood.

It is suggested that fluoride storage and feeding equipment be located in separate areas other than chemical storage and feeders. A separate dust-tight room is recommended.

BIBLIOGRAPHY

1. AWWA - Water Quality and Treatment 2nd edition.
2. Joint Committee Report - Recommended Procedures in the Use of Chlorine at Water and Sewage Plants. Journal AWWA - Oct. 1953.
3. Panel Discussion - Experience in Applying Fluorides - Journ. AWWA - Oct. 1957.
4. Panel discussion - Techniques in the Use of Liquid Alum - Journ. AWWA - Oct. 1957.
5. National Lime Association - Hoover's Water Supply and Treatment - Bulletin 211.
6. The Chlorine Institute Inc. - Chlorine Manual.
7. Edmund J. Laubusch - Chlorine Handling and Storage; Water & Sewage Works Feb. 1959.
   - Safety in Chlorine Handling: Water & Sewage Works - April 1959.
   - Hypochlorites: Materials & Handling; Water & Sewage Works - June 1960.

OPERATION AND MAINTENANCE OF PUMPS AND MOTORS

by

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An Address To
The Ontario Water Resources Commission
Basic Water Works Course
Toronto, Ontario
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OPERATION AND MAINTENANCE OF PUMPS AND MOTORS

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PUMP OPERATION

Pumps, like people, act differently under different conditions. To select pumps intelligently and operate them efficiently requires an understanding of what may and may not be expected of them.

In order that you may all understand the basic fundamentals of centrifugal pumps, I propose to have you prepare a characteristic curve for a typical centrifugal pump using test data which is provided on the sheets.

Now we have, in simple graphic form a picture of what will happen under any specified condition. The data for this curve must be carefully measured by an actual test and is always available from the manufacturer. As pump operators, you should know where these curves are and how to use them.

I was careful before to indicate that the pump we were considering was one of constant speed. As operators you may easily be confronted with a problem of changing pressure on a pumping district due to the erection of a new elevated storage tank or extension of the limits of your district or an increase of pressure due to the introduction of a second pumping station on to the existing district now served from your station. We would expect that the engineers or suppliers would be called in to help with this problem, but I

feel that as operators you should know the basic facts and be prepared to enter into an intelligent discussion. This is not hard. Don't be shy, all you need to remember are three simple rules and I would like you to commit them to memory. These three rules are:

(1) Capacity of a unit varies directly as the speed.

(2) Head varies directly as the $(\text{speed})^2$.

(3) Horsepower varies directly as the $(\text{speed})^3$.

From the characteristic curve we read that at 1200 RPM our pump will deliver or has a capacity of 4000 GPM at a head of 140 feet and requires a horsepower of 163.

If we were to operate the pump with a new motor at 900 RPM the same pump would perform as follows:

Capacity

$$\frac{x}{4000} = \frac{900}{1200}$$

Therefore $$x = \frac{900 \times 4000}{1200}$$

$$= 3000 \text{ G.P.M.}$$

Head

$$\frac{x}{140} = \left(\frac{900}{1200}\right)^2 = \left(\frac{3}{4}\right)^2 = \frac{9}{16}$$

Therefore $$x = \frac{9 \times 140}{16}$$

$$= 78.7 \text{ Feet}$$

Power

$$\frac{x}{163} = \left(\frac{900}{1200}\right)^3 = \left(\frac{3}{4}\right)^3 = \frac{27}{64}$$

Therefore

$$x = \frac{27 \times 163}{64} = 68.8 \text{ H.P.}$$

Capacity, head and power can also be changed in centrifugal pumps by altering the diameter of the pump impeller.

Assume that the original data for the pump operating at 1200 RPM was 12 inches. If we were to centre the shaft in a lathe and reduce the pump impeller to 10 inches the following pump characteristics would result:

Capacity

$$\frac{x}{4000} = \frac{10}{12} \quad \text{Therefore}$$

$$x = \frac{10}{12} \times 4000 = 3330 \text{ G.P.M.}$$

Head

$$\frac{x}{140} = \left(\frac{10}{12}\right)^2 \quad \text{Therefore}$$

$$x = \left(\frac{10}{12}\right)^2 \times 140 = \frac{100}{144} \times 140 = 97.2 \text{ feet}$$

Power

$$\frac{x}{163} = \left(\frac{10}{12}\right)^3 \quad \text{Therefore}$$

$$x = \left(\frac{10}{12}\right)^3 \times 163 = \frac{1000}{1728} \times 163 = 94.4$$

PUMP INSTALLATION AND OPERATION

(1) Pump Piping

Never use pipe smaller than the pump nozzles, and preferably use larger, especially on the suction side. Use eccentric reducers from the larger suction pipe to the pump nozzle, to prevent formation of air pockets in the pipe. Suitable tapered reducers on the suction and increasers on the discharge will ensure efficient flow on the system, and conserve power. Run all piping as directly as possible, and with a minimum of elbows and other fittings.

Never place a pipeline elbow in a horizontal plane directly at the pump suction nozzle. Between the elbow and the suction nozzle, use a piece of straight pipe, at least four to six pipe diameters long. An elbow attached in a horizontal plane, directly at the pump suction, tends to cause unequal thrust, and hydraulic losses, due to the liquid filling one side of the suction chamber and impeller eye more than the other.

Whenever possible, the suction reducer and the discharge increaser should be installed directly on the pump nozzles. This produces better conversion of flow velocity, and reduces hydraulic losses that might be caused by valves, or elbows, directly at the pump suction, and that might affect the pump efficiency.

Plan and install the suction line, so that air pockets cannot form in it. A tight suction line is essential for proper operation of any pump. Air leaking into the suction line gets into

the pump, reduces its capacity, and may cause it to stop pumping. A small air leak in the suction will cause trouble in any centrifugal pump.

Install a gate and a check valve on the discharge line close to the pump. Put the check valve between the pump and gate valve, and the tapered increaser between the pump and check valve. The check valve protects the pump against excessive surge pressure, and also against reverse rotation.

When the capacity of a centrifugal pump must be controlled by throttling, always use the discharge valve.

(2) Priming Centrifugal Pumps

No centrifugal pump of the usual type will start pumping properly, until it has been satisfactorily primed. Satisfactory priming requires that all air must be removed from the pump, and that the pump be completely filled with the liquid. Never attempt to prime a centrifugal pump while it is running. It is necessary that the pump be at a standstill while it is being primed. Under no circumstances should a pump be operated without being completely primed.

(3) Direction of Rotation

A pump should never be run in reverse rotation. Since it is sometimes difficult to determine the rotation of polyphase alternating-current motors in advance of operation, it is necessary to try them out for proper rotation, before connecting them with the pump.

(4) Packing

Do not have the packing too tight. Unduly tight packing increases power consumption, and causes rapid wear of the shaft sleeve. When first starting, back off on the stuffing-box-gland nuts, until free leakage occurs. Then draw down uniformly on the stuffing-box-gland nuts until leakage is reduced to a few drops a minute. Never tighten the packing sufficiently to prevent all leakage. A slight leakage is required to lubricate the packing, and prevent scoring of the shaft sleeve.

As leakage increases during the service of the pump to where it cannot be reduced by drawing up the gland, add another ring of packing to the stuffing-box. After a further period of operation, if excessive leakage again occurs, which cannot be controlled by gland pressure, then all the old packing should be removed from the stuffing-box, and a new set of packing rings installed. When repacking the stuffing-box, if packing rings of the exact size, cut to proper length, are not available, and it is necessary to cut the rings from coil packing, cut the required rings so that the joints are flush. When installing the rings in the stuffing-box, make sure that the joints are staggered. If the stuffing-box is fitted for a water seal and lantern ring, be sure that this ring is in the proper position when installing the new packing. Check the lantern-ring position, with respect to the water-seal line, when the packing is compressed.

(5) Wearing Rings

Wearing rings are fitted into the casing, and frequently on the impeller, at the inlet from the suction chamber, to reduce leakage from the discharge to the suction. These wearing rings have a small clearance, and depend upon the liquid in the pump for lubrication. They will eventually wear, and the leakage will increase from discharge to the suction. Rate of wear of these rings depends principally upon the character of the liquid being pumped. Since the efficiency of the pump is lowered, as the leakage past the rings increases, they should be replaced before they become badly worn.

(6) Pump Casing

Efficiency of a centrifugal pump is affected by many factors. The transition from energy of motion to pressure energy takes place within the casing. It, therefore, follows that a smooth transition is necessary for minimum losses. To this end the inside casing of the pump must be as smooth and regular as possible. Routine maintenance must be performed once every two years on all internal water passages, wire brushing, chipping, scraping, and final polishing, followed by two coats of good quality paint. This is essential for high efficiency.

MAINTENANCE OF ELECTRIC MOTOR

An electric motor is the most important type of machine used for driving rotating equipment, like centrifugal pumps, for reasons of costs, simplicity of operation, and ease of maintenance.

The most common type of motor for centrifugal pump operation is the squirrel-cage induction motor.

Compared to a gas engine, with hundreds of moving parts, the induction motor has only one moving part, the rotor. Maintenance of the rotor bearings, if of the oil sleeve journal type, is the most important and the most frequent.

Another important maintenance requirement of electric motors concerns heat.

In this discussion, consider a common induction motor rated as follows:

200 H.P., 3 phase, 60 cycles, 1185 R.P.M.

The efficiency of the motor is 94 per cent.
The power input = 200 ÷ .94 = 212.8 H.P.

Power losses, due to the resistance in the windings and friction, etc., account for 6 per cent of the total power input, or 212.7 x .06 = 12.8 H.P.

This power is unable to perform useful work, and is converted to heat. To illustrate how much heat is developed, if the heat losses from this motor were applied to one gallon of water, at room temperature (72°F.), the water would boil in 2½ minutes.

The manufacturer has designed the motor to remove this heat, by providing ventilating ducts and fans, and has protected the windings against an allowable quantity of heat, by use of such

materials as mica and glass.

However, if dirt and dust are permitted to build up on the windings, and clog ventilating passages, the machine will not be able to waste sufficient heat, and the ensuing temperature rise will reduce the efficiency of the motor gradually to the point of insulation breakdown, and possible machine failure.

To prevent this, the atmosphere in the pump room should be kept free from dust, and the motor itself should be cleaned by an electrician once a year.

MAINTENANCE OF MOTORS

(1) Keep dust removed. Dust insulates windings against the loss of heat, thus interfering with proper cooling; a mat of dust will retain oil and moisture. On slip rings and commutators, dust causes wear and poor electrical contact. Wipe off housing and rings regularly, and blow the dust from the windings with a clean air jet (never above 40 psi. pressure) or hand bellows. Keep oil cups closed, to prevent access of dust to the bearings.

(2) Keep free from stray lubricating oil. When oil-soaked, the insulation is softened, and liable to burn out. Good contact is impossible with dirty commutators or rings. Oil and dust deposits are removed by carefully scraping, or wiping with a solvent like carbon tetrachloride. Avoid soaking the insulation. Never lubricate oil ring reservoirs while the motor is running, as overfilling and spread of oil may follow when the motor is stopped.

(3) Keep motor as dry as possible. If a megger test shows a low insulation resistance, due to moist conditions, the motor may be dried by passing a low voltage current through the windings, with the armature locked stationary. A fan to blow air through the windings aids evaporation. During long idleness, cover the motor with a tarpaulin, and keep dry by the heat from a couple of light bulbs. When flooded, a motor may be reconditioned by controlled oven baking, by infra-red rays, or by a bath in hot paraffin.

(4) Keep bearings properly lubricated, according to manufacturer's recommendations. Bearings should be inspected at least weekly. Oil rings in sleeve bearings should rotate freely with the shaft.

(5) Keep commutator, or slip rings, smooth. Good operating condition is indicated by a clean, polished brown color; a bluish color signifies overheating. If worn in grooves, resurface by means of a commutator stone; never use emery cloth, nor an emery stone. Reset brushes, or renew them, if more than half worn. Check brush pressure, and clean brush holders if dirty.

(6) Do not overload the motor. The resulting heat may melt soldered connections, and bake the insulation. Overload protection is obtained by an overload relay, or proper sized fuses.

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DISTRIBUTION SYSTEM MAINTENANCE

by

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DISTRIBUTION SYSTEM MAINTENANCE

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INTRODUCTION

Maintenance comprises those operations which serve to keep a system functioning properly. Repairs, on the other hand, are those steps taken to replace broken or worn parts of the system. Since these two terms are not given the same meaning by everyone, we shall use the term preventive maintenance to mean ways of keeping a system functioning without costly breakdown.

MAIN LINES

Adequate maintenance of any part of any system requires a supply of proper tools, equipment and repair parts. The tool supply should include pumps, cutters, wrenches of all types, air tools, caulking tools and various kinds of small hand tools. When a large line is cut or broken, the best available pump should be used. Caulking tools are needed when lead joint pipe is used in the system. Air tools save valuable time when it is necessary to cut through a paved road. Various types of pipe cutters may be used but when it is necessary to remove a section of pipe it is handy to use a cutter such as the Strickler ratchet cutter which removes about 1/8" of the pipe allowing easy removal. It also helps to eliminate the danger of breaking the pipe which is to remain in service. In making any cuts in a pipe it is important to cut only as much as required and if possible to make all cuts square which enables better joints where fittings are to be installed.

Various other types of equipment are used which help to save time and money during repairs. There are for example, two way radios which cut down the number of men required to maintain the system; leak detectors which have the obvious advantage; pipe locators of all kinds are used for spotting underground pipes and where there are many underground lines a special wireless electric locator is used; a valve box locator, which is no more than an inverted compass which will pick up almost any metal items such as valve boxes, meter boxes or sewer manholes and is especially handy in case of emergency.

A good supply of repair parts is important as any repair job can be costly if it has to be patched up until the parts are available.

The maintenance of main lines has become one of the biggest jobs. The reason for this is the street reconstruction which requires the pipe to be relocated, lowered or offset.

When lowering a line it should be let down slowly and the offset in each joint kept the same. Care should be taken that the deflection in each joint not be permitted beyond the maximum limit. As an example, when lowering an eighteen foot length of eight inch diameter cast iron mechanical joint, never let each such length of pipe deflect more than 20". The maximum allowable deflection for any pipe or joint size can be found in the manufacturers hand book. If the pipe being lowered has lead joints it is necessary to recaulk each joint.

If an offset in a large line is to be made with bends, it is recommended that straps be used to hold the bends in place. All bends must be firmly blocked before the water is turned on as any pressure surge on an unsupported bend can take it right out. An offset is made by joining two 1/8 bends together.

Many kinds of fittings and repair parts are used in line repairs and a few of them are listed here.

The split sleeve can be used for repairing broken or split pipe. There is a special kind of split sleeve made for repairing broken bells. This sleeve may also be used for joints that slip away from home. When repairing a section of pipe that needs several lengths, the pipe can be replaced and the last two pieces can be raised and "buckled in".

Worn out or broken steel pipe can be repaired with a flexible type coupling.

Broken transite pipe can be repaired with a special transite sleeve for transite pipe. Short machined lengths are manufactured which are inserted into the broken points of the line.

GATE VALVES

In a new system the maintenance of gate valves is limited mostly to the repair of stuffing boxes and valve boxes. There are also always cases where the valve is damaged but with careful installation this should be at a minimum. In such a case it is

necessary to replace the broken part. Valve stems, gates, wedges or other parts can often be repaired with the body of the valve still in the main line.

In every system there is the need for annual valve inspection. This is done to find valves that are closed, or have some minor defect. Left hand valves should be clearly marked if not replaced.

When a valve is closed, and water still passes the gate, the valve should be opened just enough for water to pass under the gate. This usually washes out anything that is stopping the gate from closing properly. If the gate, is not effective after several repetitions of this the gate should be removed from the valve. Any obstruction below the gate can be removed and any worn parts replaced.

Some valves are hard to close and occasionally too much force is applied to them by say 4 or 5 men. When the gates are tightened down too much, they are sometimes warped and thus water can pass above the gates. The stem can also be twisted which will cause the gates to blind.

A record showing the accurate location of every main line valve should be kept. This should be a detailed drawing showing measurements from various permanent marks or objects e.g. property lines, manhole covers, catch basins, fire hydrants, curbs, sidewalks, hydro or telephone poles.

Valve boxes should be kept up to grade at all times. Some may have to be raised several times but in the event of an emergency it is important to be able to locate a valve quickly.

HYDRANTS

Of all the points of maintenance in a distribution system, hydrants could be one of the easiest if a little preventive maintenance is used when the hydrants are installed.

One of the major problems in larger cities and towns is the location of hydrants to be away from potential traffic damage. In cold climates with severe winters it is very important that hydrants be pumped out immediately after use to prevent freezing and cracking.

A suggested procedure for hydrant inspection is as follows: -

1. Use a sonascope and listen for underground leaks.
2. Check gate valve and valve box.
3. With the caps on, open the foot valve and check the stuffing box and nozzle caulking.
4. Close the foot valve, remove the caps, and check the drain.
5. Flush the hydrant.
6. Check and grease the threads on the nozzles and caps.
7. Check obstructions to use.
8. Oil the operating nuts.

METERS

The most important and most obvious requirement of a meter is that it should register all flows accurately. Actual tests carried out on inaccurate meters would not register low flows. It was also shown that in most residential areas, about 27 to 54 per cent of the total consumption is at flows of less than 0.5 gall/min. Thus for an economic production and distribution of water, accurate figures of consumption to be applied to water bills must be maintained.

In some systems a time limit plan is used, such as a 5, 7, or 10 year plan. The 7 year plan is about the average for most systems and they usually start off by pulling all meters out of service that have been in use for seven years or longer. The time limit plan is not always effective when for example the water being metered is non active and none corrosive so that a large percentage of meters become inoperative from broken registers. In such cases it is better to check the meter readings monthly from which it can usually be determined if inaccuracies are apparent.

TANKS

The life of a tank depends upon a thorough and regular inspection and prompt repair of it when repairs are necessary. Another item that determines the life of a tank and supporting tower is the type of water and weather conditions. The regularity of inspection depends on the type of system used and its location.

Tank inspections should be made after every storm and flood. Regular inspections are usually made in the spring of the year to allow plenty of time for repairs during the good weather.

The inspection is made to determine the extent of pitting or paint failure by blistering, peeling, rusting, or abrasion. It should also state whether or not the pitting is in spots and can be repaired by welding or whether the pitting is general and requires new sheets or structural members. The inspection report should contain as much detail on the condition of the tank and any recommendations for repair.

During the inspection of the inside of the tank, some safety measure should be put into practice, because ladders and spider rods are usually the first to deteriorate.

CONCLUSIONS

We in the business of "manufacturing" potable water too often forget that the eventual target of our endeavours is the consumer, whether domestic or industrial. Bearing this in mind it must be obvious to us that our efforts in the pumping station or filtration, our calculations and measurements on chlorine feed rates and micro-strainer operation comprise the first step in reaching our target. The second step is the care and maintenance of the distribution system which is equally important for without due consideration to this our other activities can be almost meaningless.

Let us consider the factors involved in the distribution system which affect our final target. If leaks in the distribution system go undetected our consumers suffer through decrease in water pressure. We and the municipality suffer through loss of water and again the consumer suffers either through paying higher rates for water or higher taxes.

Where breaks occur in the system and proper cleaning and sterilizing is not carried out before and after repair then the consumer suffers with water which may be contaminated or have a taste, odour or colour. The bad publicity and possible health hazard from such occurrences are certainly undesirable.

Neglect of the simple valve can cause extreme inconvenience to the consumer in the event of a line break, where it is necessary to close off much more of the line during repairs than is absolutely necessary.

Care and maintenance of meters should be rather obvious to ensure that no consumer is billed for a greater quantity of water than was actually consumed and conversely no consumer is using more than he is paying for.

From this discussion it can be easily seen, that taking our starting point from the careful installation of an intelligently designed system, it is quite simple and relatively inexpensive to maintain the distribution system satisfactorily.

RECORDS AND REPORTS

by

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An Address To
The Ontario Water Resources Commission
Basic Water Works Course
Toronto, Ontario
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RECORDS AND REPORTS

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A record may be defined as a compilation or collection of figures, facts or data relating to an event or sequence of events. A report, on the other hand, is an explanation of the facts or figures that appear on a record.

The maintenance of records, or the collecting of figures to compile them is considered by many of us as a time-consuming task, a thing which someone thinks we should do, but for which many of us can see no important purpose.

Still, our very existence, professionally and otherwise, is one record after another and we maintain these records either mentally, to be forgotten as soon as the data is received, or kept in permanent form for future reference. Records are used, also, for the regulation of daily affairs and future planning. We all keep them and use them constantly; e.g. a bank book which aids in guiding present and future expenditures. If we do not maintain a bank account we have no money, or we bury our wealth in a hole in the ground. Even in the latter instance we keep a record of where the burial spot is.

Again, we accumulate records of our car mileage and how much gas we use. As soon as we calculate the miles per gallon of gas used, for someone's information, we are making a report based on the data collected from our car mileage records.

Indeed, there is nothing peculiar about our maintaining records and preparing reports. Only the degree and the type of information desired differentiates between them.

We can apply the above to the operation of a water works or a water works system. The records we keep and the reports we make can be categoried as:

1. Operational records;
2. Maintenance records;
3. Statistical records;
4. Accounting records.

The information contained in each record may overlap depending upon how the record form is composed. Data of an operating nature may also relate to maintenance and/or statistics. This information will vary with the type of plant, the size of the plant and the method of treatment, the source of raw water and the extent of the distribution system. Data recorded may be on an hourly basis, semi-hourly, once a shift, twice a shift, weekly or monthly basis. Your records may be voluminous or sketchy, but in each case relative to what you want or need in order to operate your plant efficiently. Regardless of the form in which you are required to accumulate data, you will probably record additional information for your own broader understanding.

Records relating to the operation of the treatment plant may include information incorporating filter runs, wash water used, pumps in operation, chemicals used, condition of the raw and treated water, flows, chemicals on hand and on order,

chlorination rates, power consumption, power factors, periods of maximum electrical demands, weather observations, and results of laboratory control tests used by you to assure the adequate treatment of the water delivered by the plant. If your initial supply is from wells you will be interested in recording well drawdowns and rates of aquifer replenishment. If your supply is from streams or lakes you will, no doubt, desire to record stream levels or lake levels.

In order to set up a system of adequate records two essential elements must be remembered. Firstly, the form and extent of the records to be kept must be carefully planned. Secondly, a procedure must be established to insure the continuance of the records selected. This is most important because a given set of operating conditions, if not recorded immediately, can never be accurately reproduced.

In the case of distributing systems, the records relating to the operation and maintenance of the system are not static and definite procedures to insure that information will flow from the field to the control point are necessary. A record of primary significance to the operating and maintenance of a distribution system is a comprehensive map. This map should be on as large a scale as possible and should show all mains, main sizes, types of mains, valves, hydrants, streets, reservoirs, elevated tanks, wells, booster stations, and emergency interconnections with other systems. If possible, blow-offs, air release valves and normally closed gate valves should be indicated. The original map should be carefully stored and copies issued to operating personnel for their use. As the map must include the

entire system, the scale may be too small to show the required detail. Therefore, to have an adequate record it will probably be necessary to divide the map into sections on separate sheets, using an adequate scale to show the requisite detail. Sectional maps must be accurately scaled so that adjoining sheets will co-incide. Information on sectional maps will show subdivisions, lots, blocks, tracts, streets and easements, street names and widths, mains, size of mains, location, material, year installed, hydrants, type, class of hydrants, details relating to valves, service lines including size and location, and all other pertinent information relating to the system or section of the system under study. In other words, the section map is a magnified part of the major system map which enables you to read the fine print. In large distribution systems it has often been found advisable to enlarge or divide section maps for issuance to works foremen assigned to particularly congested areas. In preparing a section map it may not be possible to obtain all the desired information in an economically short time. This information may be omitted until it can be obtained without undue expense.

In any event, sectional maps are among the most important of all distribution system records. Supplementing these maps, and for use of the field crews, are valve records. Valve records are lists of all gate valves with their location, function and operation. Data is given as to valve number, size, make class, number of turns to open, direction of turns

to open, street location, distance and direction from the principal street line or curb, and intersection or other information to help rapidly locate the correct valve.

Maintenance records on each section of main, each valve, hydrant, or blow-off on the system can be set up to show the trouble experienced, remedy, time and material required to effect repairs, and the costs involved. By accumulating records of this nature, it is possible for supervisory personnel to evaluate types of material or equipment, forecast future trouble spots, set up preventative maintenance procedures and prepare maintenance budgets. Maintenance records can be most easily compiled and kept as a running record by employing card reference files. The use of cards will:

(a) Simplify the procedure to be adopted for adequate maintenance and lubrication of all equipment.

(b) Establish correct time intervals between lubrication of equipment.

(c) Establish a policy of preventative maintenance for all equipment.

(d) Establish, where possible, a standardization of maintenance practices and lubricants for more efficient and economical operation of plants.

(e) Remove from the operator the burden of remembering when maintenance and/or lubrication should be carried out.

(f) Provide an accurate lubrication record of each unit or piece of equipment.

Information on the card usually includes all pertinent information relative to the unit to which it refers. Each unit will have a card which will identify the equipment by a

plant number and will list name plate data, model, serial number, manufacturer, supplier service representative, lubrication instructions by type and grade of lubricant and frequency of lubrication. A category on the card is for a brief description of repairs made, parts replaced, servicing and repair costs. Some operators color code the cards for lubrication inspection or overhaul periods. The use of colored cards will enable the operator to quickly identify equipment requiring various intervals of inspections, routine maintenance and lubrication. Periodic spot checks by the plant superintendent will give immediate indication of whether routine maintenance instructions are being carried out.

Much of the data accumulated on daily operating log sheets may be classed as statistical in nature. Such data deals with hourly flows, maximum and minimum flows, total flows, power consumption, quantities of chemicals used, water conditions, periods and times of maximum power demands, hours of pump operation, and many other factors that can be compared with past records and be used for forecasting future operating conditions. Close comparison of these figures show many interesting features. For instance, it has been possible by the collation of total flows to indicate to main crews that a leak has occurred in the distribution system. Cost of operation, total flows and plant capacity will provide data which may influence the provision of meters in the system or metered supplies to the users. Periods of maximum power

demand will give you clues as to when to start auxiliary, mechanically driven pumping units thereby reducing monthly power bills and, in turn, plant operating costs. Total flows or maximum flows may indicate the necessity for increasing plant capacity or revising plant design.

All accounting records may not come under the jurisdiction of the plant operator, but information including inventory control, costs of maintenance, and time or payroll data do. From the point of view of the operator, the payroll records are highly important. If they are not accurate and if they are not submitted to the central accounting point on time, he, necessarily, will receive complaints. With the development of machine accounting, many of the major accounting records are maintained in the form of punched cards. The advantage of punched cards is that much information can be included on them in a small space. Later, these cards can be used for billing procedures and collection data.

Another useful record is the diary or daily log book. Many miscellaneous incidents in plant operation do not fit into the regular records employed, however they should be kept in some type of permanent form. Such information noted might include: occasional numerical data and measurements, maintenance items, replacements and repairs, start-ups, trouble and various methods tried for correction in start-ups or treatment, complaints from

customers, visits by officials or authorities and their comments, reports from other agencies such as the Department of Health re inspections and tests, and similar facts that an operator always appreciates having on hand. This data may be quickly referred to if the daily summary sheet of operation contains a cross reference. Instances arise where knowledge of the date of an occurrence, even without further detail, is helpful.

In this dissertation I have not attempted to relate what records should be kept, what data should be recorded, or how often data should be recorded. I have merely indicated a few suggestions as to what some operators may keep in the form of records. In the final analysis, the records you keep will depend on the type of plant you operate, the amount and category of information you require for answers to inquiries, and what information will enable you to operate the plant efficiently and economically. I have also tried to stress the great importance of accuracy and the need for continuity in your records. Also, attention has been directed to some of the ways in which this information is used. Finally, if records are carefully assembled and analysed, they can be of much assistance to you and to your supervisors.

SAFETY PRACTICES IN WATER WORKS

by

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An Address To
The Ontario Water Resources Commission
Basic Water Works Course
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SAFETY PRACTICES IN WATER WORKS

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INTRODUCTION

The theme which must be stressed in all safety work is that the greatest asset a water utility has is its personnel, and good business dictates that this asset be protected as vigorously as possible. Thus, good utility management demands that a well co-ordinated and vigorous safety program be instituted at all water utilities. The mere lack of a safety program at a water utility would indicate that management is not alert to its duties.

A SAFETY PRACTICE PROGRAM

Before a safety program can be established, it must have the full co-operation and active support of management. It is imperative that one person in the utility organization be designated as responsible for the program. In a small water works system, that person may be the superintendent, while in larger organizations another person who can devote part or full time to the job may be so designated.

The next step in setting up the program is to provide for: (1) keeping injury records, (2) locating the hazards, (3) making equipment, plant arrangements, and working methods safe, (4) getting employees interested in safety, and (5) controlling work habits.

INJURY RECORDS

The keeping of injury records is basic to a safety program. With complete records, the program is given direction and is sure of success. The records should be short and contain space for all pertinent data. The forms should cover such items as: (1) accident report, (2) description of accident, (3) physician's statement, (4) corrective action taken, and (5) accident analysis chart.

LOCATING THE HAZARDS

The person responsible for the safety program should constantly be on the alert for hazards which may cause an injury to an employee. One of the best methods of attacking this problem is to search the records for the conditions and situations that have produced injuries. Records such as this provide evidence of the need for a corrective program.

Many other sources of information on hazardous conditions are available. These include safety manuals, insurance company brochures, etc. These sources of information should be used freely and frequently.

EQUIPMENT, PLANT ARRANGEMENTS, WORKING METHODS

Nothing prevents accidents as effectively as the elimination of the causes. To preach safety while permitting unsafe conditions to prevail is bound to create an obstacle to the co-operation required from employees. Only when safety is integrated into the job are workers convinced that the man responsible for safety wants to prevent accidents.

EMPLOYEE INTEREST

To obtain maximum benefits from a safety program, it is essential that everyone in the organization become interested in and sympathetic to its objectives. The answer to full co-operation by the employees lies in a carefully thought out program, real knowledge of human beings and their actions, a knowledge of the work and of union organization, and endless, painstaking, thorough attention to the program by the people who administer it. A basic point is to get everyone into the safety picture at once, and keep them in it.

CONTROLLING WORK HABITS

There are always several ways to do a job, some of which are not safe. Work methods for all routine jobs should be analyzed and standardized on one safe way. These safe ways for doing a job should be impressed upon the workers until they not only accept the methods, but the methods for doing the work become habitual. Thus, safety becomes a habit.

SAFE WORK PRACTICES

The accumulated records, statistics and information become of value when used for analysis because they permit closer concentration toward accident-prevention in the most hazardous areas. A study of the causes, the types, and the sources of accidents may call for closer supervision, additional training, and/or education in certain fields of operation. It is in this analysis that the safety program can make its best efforts and eliminate or minimize accidents and injury.

PHYSICAL EXAMINATIONS

An initial corrective measure in setting up safe work practices is the determination of the workman's physical ability to perform the duties at the time of his employment by requirement of a physical examination before employment. Many potential accidents can be eliminated at this point when physical defects can be found that may prove the workman's inability to perform a particular job. This examination may also reveal accident proneness or previous history of occupational accidents and injuries.

INDOCTRINATION

The indoctrination of new employees is very important. This should be done at the time of employment, again by his supervisor, and then as on-the-job training by his immediate foreman. This is the point where the employee developes the safe work habit.

ON-THE-JOB TRAINING

Since safe work practices are the responsibility of the foreman as an essential part of his job, he must see that each workman fully develops the safe work habit. On-the-job training demands that safety be a part of job planning and job performance.

CORRECTIVE ENFORCEMENT

When the foreman-supervisor is assigned the responsibility for safety, he must also be given the authority to see that safe work practices and conditions are carried out. When an employee becomes an accident repeater or when he fails to maintain safe working practices or the proper personal safety attitude, efforts must be made to rehabilitate the employee through counselling, closer supervision, or reassignment. Continued lack of co-operation or failure to comply with safety responsibilities should be the cause for corrective disciplinary action.

SAFETY IN WORK PRACTICES

It is not intended that the following suggestions will completely cover all methods of safe operation. Time does not permit a complete discussion of safe work practices. Many texts, manuals, and publications have devoted considerable time and effort to this subject and are available and recommended for more detailed practices. These suggestions should serve as a reminder to all personnel that safety is the basis of doing the job efficiently.

ACIDS, CHEMICALS, GASES

ACIDS (CORROSIVE)

Meter shop, acid room, or other areas where solvents or other compounds are used must be well-ventilated. Protective clothing and equipment must be worn while working in a meter shop acid room. The working area should be designed and

constructed for the safety and convenience of the worker and for his efficient production.

ALUM

Protective dustproof equipment and proper clothing should be worn by personnel handling and storing. Skin and nose irritations may be avoided by the use of plenty of water in washing and bathing.

AMMONIA

Cylinders should be stored in a cool, dry, ventilated place, and handled with care. Protective equipment should be available while handling; and in case of leaks, only trained personnel should make repairs. First aid practices should be known to persons handling and using this material.

ACTIVATED CARBON

Storage should be in a dry fireproof space. Activated carbon should be handled with protective dustproof equipment. Smoking must not be permitted while working with or near stored material. Plenty of water should be used in washing and bathing.

CARBON MONOXIDE

Work on engines using gas, gasoline or diesel fuel should be carried out in well ventilated areas. Improperly vented gas heaters should be corrected.

CHLORINE

This subject will be dealt with in a later section.

FLUORIDES

Fluorine compounds, in general, are very toxic, and only trained personnel should handle this material; proper protective equipment and clothing should be used. Storage should be in a specific, well ventilated area. Plenty of water should be used in washing and bathing and in cleaning of equipment used to handle material.

HYDROFLUORIC ACID

Extreme care should be taken while handling or using, since severe skin, eye, and nose irritation may be caused by a weak concentration (it is fatal in heavy concentrations). Personnel handling this material should be thoroughly familiar with the hazards of this acid.

LIME

Protective dustproof equipment should be used while handling, and a dust collecting system used, if possible. Storage should be in a ventilated, dry area. Plenty of water should be used in bathing and washing to prevent irritations - and physicians should be consulted if irritation becomes severe.

SODA ASH

Soda ash should be handled in the same manner as described previously for lime.

SOLVENTS

Care should be taken when solvents are used in confined areas. The area should be well ventilated. Solvents should be cleaned from skin to prevent irritations.

AIR HAMMERS - TAMPERS - PAVEMENT BREAKERS

Each operator should be thoroughly instructed in the use of this equipment. Foot guards and eye protection should be worn. No horseplay should be tolerated. Routine checks should be made of the equipment and it should be maintained in good condition.

AUTOMOTIVE EQUIPMENT

Drivers must be licensed operators and know and observe all traffic regulations. Drivers should be instructed as to responsibilities for company equipment: to see that equipment is always in safe driving condition, to report the need for necessary repairs, to know procedures for reporting accidents and injuries and to attend periodic safety meetings of equipment operators.

BARRICADES AND TRAFFIC CONTROL

An adequate and safe work area must be protected. Sufficient traffic cones and barricades should always be carried by crews assigned to construction or maintenance work in streets. Barricades should be painted bright, visible colours and maintained in good condition. Warning signs, flags, flares

should always be adequate, and in positions where they can be observed easily.

BUILDING MAINTENANCE

Periodic inspections are necessary to eliminate hazards (fire, safeguards, etc.). Suggested repairs for safety should receive immediate attention. Floors, hallways, and stairways should always be well lighted, clean, orderly, and free from oil, dirt, and debris. Immediate repairs of hazardous electrical outlets and fixtures should be routine. Adequate sanitary facilities for employees must be provided. Hand rails on steps and stairways should be provided and used. Good housekeeping should be provided and used. Good housekeeping must be maintained.

CALKING AND USING LEAD

Proper eye protection must be used. Proper tools in good working condition should be employed. Lead melting should be done out of work traffic, by workmen using face protection and gloves, and having thorough knowledge of handling lead.

CHLORINE HANDLING AND TRANSPORTATION

Only properly and thoroughly trained personnel should handle and use chlorine.

Storage should be in an area that is accessible, dry and cool, where minimum amount of handling is required. Storage of small units should be in upright position, and ton units on their side,

with platform and proper lifting equipment used for handling. Chlorine leaks should be handled only by trained and authorized personnel.

Proper gas masks should be available outside of the chlorine room or area. At least two men should be available for leak repairs (one as a safety standby). Only proper-fitting wrenches should be used on valves. Safety repair kits should be available to large users. When leaks are detected, valves should be closed; if liquid chlorine, position of container should be fixed that only gas escapes. Water should not be sprayed or poured on a chlorine leak. An ammonia swab can be used to detect leaks.

The following first aid steps should be taken in cases of chlorine accidents:

(a) remove injured to open air,
(b) call physician,
(c) lay injured person on back, keep warm and quiet, and start artificial respiration if unconscious,
(d) administer hot black coffee,
(e) apply burn lotion or oil for relief of skin irritation and,
(f) relieve throat irritation and coughing.

FIELD CHLORINATION

Trucks and equipment should be driven carefully. Only properly trained and authorized personnel should operate and use equipment. Equipment should be checked regularly for safety hazards, for safety equipment and proper tools. Children or unauthorized persons should not be permitted to operate or be near the equipment. A safe working area should be provided and maintained.

AIR COMPRESSORS

Air compressors should be inspected periodically. Necessary repairs should be reported and repairs made immediately. Trailer hitch connections should be made and secured safely. Equipment should never be refueled while in operation. Hose connections should be maintained securely.

HOISTING CRANES

Only trained and authorized personnel should operate hoisting equipment. Hoisting gear should be adequate and proper for the load. The operator should stop equipment immediately when a hazardous condition develops.

DOG BITES

Dog bites are a definite hazard to meter readers and outside workmen, and should receive prompt medical attention.

ELECTRICAL CONSTRUCTION AND MAINTENANCE

Only authorized and fully competent personnel should be assigned to work with electrical equipment and maintenance.

Switchboards and equipment should be designed and located in clear, well lighted, accessible, insulated areas. Personnel should wear insulated safety hats when working in hazardous areas. Safety equipment should always be available.

An electric shock victim must be given prompt and correct attention immediately. However, the rescue and reuscitation of a shock victim requires considerable skill and should be attempted only by those trained in this type of rescue work.

FIELD ELECTRICAL HAZARDS

Checks should be made for electrical hazards on construction or maintenance jobs when work is planned.

ELEVATORS

Only authorized personnel should operate elevators; controls should be tested daily before operations begin. Proper warnings and signs should be posted and area kept clear when elevators are being repaired or out of service. Periodic inspections should be made.

EXPLOSIVES

Explosives must not be used by any other than authorized, experienced and certified personnel. Extra precautions should be taken by the foreman-supervisor in regard to the safety of the operator, the area, the job, and the equipment.

FALLS

Since many serious accidents and injuries occur because of falls, employees must frequently be cautioned of this hazard.

Good housekeeping prevents many accidents from falls - objects falling, and the person himself falling. Work areas should be clear and orderly. Stairways and floors should be clear, clean and orderly. Safety belts should be used when workmen are in awkward positions or in high places.

FIRE PROTECTION

Good housekeeping is the basis for fire prevention. Inspections should be made periodically, and correction of fire hazards should be made as soon as practicable. Local fire departments should be consulted for recommendations.

HAND TOOLS

Hand tools, improperly used and in unsafe condition, are the cause of many accidents and injuries. Therefore, the right tool should be used for the right job in the right way. Protective safety equipment should be used where there is a job hazard. The work area should be in a safe condition, clear of hazards, with an adequate working space allowing a solid footing. Tools should be in good condition and used for the purpose for which they were intended.

HORSEPLAY

No horseplay should be permitted on jobs. Many serious accidents and injuries are caused by horseplay and immediate corrective action should be taken if it is repeated.

INSPECTIONS OF TOOLS AND EQUIPMENT

Periodic inspections should be made of tools and equipment so that those that are broken or worn out may be replaced. Worn or broken equipment should be reported, and replaced or repaired as soon as practicable.

LABORATORY

The working area in the laboratory should be adequate, well ventilated, well lighted, clean, orderly, and equipped with proper supplies and equipment. Housekeeping is of utmost importance. Protective equipment should be available, that is, aprons for acids, hoods for fumes, acid storage, safety valves on autoclaves, etc.

LADDERS

Ladders should be inspected periodically and maintained in good order. Safety belts should be used when awkward positions are necessary for the work. Metal ladders should not be used for electrical work.

LANDSCAPING

Personnel should be properly trained in the use of power equipment, especially power lawnmowers. Equipment should be completely disconnected, and care should be taken while repairing or cleaning equipment. Safety belts should be used if workers are required in high or hazardous places.

LIFTING

Lifting should always be done with the leg muscles instead of the back, and footing should always be secure. Knees should be bent and back kept straight, and body must not be turned or twisted when lifting. Assistance should be secured if load is too heavy or awkward to handle. Use mechanical device for lifting wherever possible.

OFFICE SAFETY

Working areas should be adequate, well ventilated, properly lighted, and arranged so that desks, chairs and equipment will not be hazards to passage for work. Good housekeeping is important. Electrical equipment should be repaired by qualified personnel only. Horseplay must not be permitted.

PAINTING

Inside painting should be carried out in a well ventilated area. Proper protective masks should be used when spray painting. Good housekeeping is essential in order to prevent fire hazards. Care should be taken as to the proper use of ladders, scaffolds, etc. and safety belts should be used when working in high or hazardous positions.

PORTABLE AND POWER TOOLS

All equipment should be safeguarded by grounding. Wiring and equipment should be checked periodically for defects. Extreme care should be taken when equipment is used in wet areas.

Protective safety equipment should be used when using grinders, buffers, or other tools if there is a danger of flying material.

PROTECTIVE SAFETY EQUIPMENT

The need for protective safety equipment in an accident-prevention program has proven its value many times, and the program cannot be successful if any phase of accident-prevention is overlooked.

Safety equipment should be used as designated, and its use should be compulsory by workmen performing hazardous work. Eye and face protection should be used in jobs where there is any possibility of injuries, that is, from hand tools, power tools, welding equipment, etc. Foot protection should be used to safeguard against injuries while breaking pavements, tamping trenches, handling materials, etc. Head protection (safety hats) prevent many serious injuries in construction, excavation or electrical work. Hand protection (gloves) should be used to prevent injuries occurring when handling materials, sharp objects, chemicals or electrical equipment. Masks and respirators should be used when such hazards exist such as chlorine, painting or dusty areas. Prevention of accidents due to falls can be minimized by the use of safety belts, scaffold, etc.

SANITATION

Washrooms, toilets, locker rooms, drinking fountains, and showers that are clean, ventilated and adequately built keep good employee morale. Adequate, clean drinking water

and paper cups should be available to workmen in the field. Sufficient showers should be available at each plant, especially if the employees are exposed to skin irritant materials.

STAIRWAYS

Stairways should be well lighted, clear and orderly, and have hand rails. Caution signs should be posted to draw attention to the safe use of stairways and hallways. Steps should be always clean, and skidproof material properly installed, if necessary, to prevent slips and falls.

STORAGE AND HANDLING MATERIALS

Mechanical hoisting equipment should be used on heavy or bulky materials when lifting or handling hazards are present. Personnel handling material should be instructed in the proper method of lifting.

Proper protective equipment should be used when material being handled requires its use. Material should never be suspended over workmen. Storage space in material yards and storerooms should be adequate, clean and orderly. Pipe storage should be in an accessible area, properly and securely stacked, and well braced.

STOREROOMS

Good housekeeping must be maintained at all times. Space should be well arranged to permit proper storage, handling and movement of materials. Inspections should be made periodically

for fire hazards. Fire extinguishers should be in good order and easily accessible locations.

ELEVATED TANKS AND RESERVOIRS

The ground area surrounding elevated tanks and reservoirs should always be neat, clean and landscaped, if possible. Tanks and reservoirs should be kept in good condition. Protective fencing should be provided to keep out unauthorized persons. Ladders should be securely fixed. Safety belts should be used when working in high or hazardous positions. More than one workman should be present for work or inspections. Care should be taken when power equipment is operated to eliminate electrical hazards.

TOOLS AND MACHINES

Protective equipment should always be used when operating power equipment where there is any chance of flying objects or other injuries. Inspections should be made of all tools and equipment for safe operations, and necessary repairs or replacements should be made immediately. Repair of power tools and machinery should only be made when the equipment has stopped.

TRENCHING (EXCAVATION - SHORING)

Safe and adequate work area should be well protected with barricades and traffic safety cones for the protection of the worker and the public. Proper and adequate tools and equipment should be available for the job to be done.

Workmen should use proper protective safety equipment, that is, safety hats, goggles, foot guards, shields, etc. Inspections of the trench should be made for possible hazards - checking for possible cave-ins, projections inside trench, housekeeping, etc. Equipment should be operated by authorized and qualified workmen only.

Since most serious injuries occur in the field, extra precautions should be taken of work safety and conditions of men in the trench. Never take chances while workmen are in the trench. Proper shoring and bracing always pays.

TRUCKS AND EQUIPMENT

Trucks and equipment should have routine inspections made. Need of repairs should be reported and made as soon as practicable. Only qualified and licenced operators should be permitted to use and operate vehicles and equipment. Operators and drivers should not permit riders on equipment or permit passengers on trucks or equivalent equipment when it becomes hazardous. Electrical or other hazards should be checked constantly when moving heavy equipment.

WELDING

Proper protective equipment should be used at all times. Checks should be made for possible fire hazards, cutting or welding in areas of inflammable or explosive mixtures. Only authorized or capable personnel should operate welding equipment.

WORKING AREA

A safe working area must be provided for efficient work to be done. In the field, traffic should be controlled by the use of traffic cones, barricades, flags, etc. to give protection to the workmen as well as to the public. In the material yard and storerooms, good housekeeping and properly planned storage and work areas must be provided to permit safe working practices. In the shops, plants, and offices, planned arrangements must be made to provide safe working areas to enable the most efficient production.

CONCLUSION

Through continuous research and accident experience, standard safety rules and safety devices have been worked out for most of the operations which are common activities in water utilities. We, as supervisors, are expected to know about these rules and devices, and we are also expected to use them. We must broaden our horizons in safety, by learning what others are doing, so that we may have a wider understanding to help us work out protective devices and safe practices of our own to fit our own operations. No matter how perfect the mechanical device or how thorough the research and development have been, the degree of hazard for safety of the operation rests in your hands.

RESEARCH OPPORTUNITIES FOR OPERATORS

by

G. Kay

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An Address To
The Ontario Water Resources Commission
Basic Water Works Course
Toronto, Ontario
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RESEARCH OPPORTUNITIES FOR OPERATORS

G. Kay

District Engineer - OWRC

Good afternoon gentlemen, it is a pleasure for me to have an opportunity to address you today and I should like to discuss with you, Research Opportunities for Operators.

By this time you will have discovered that on this course, each man is associated with a water works which uses surface water or ground water supplies, filters, or does not filter, chlorinates or does not chlorinate, softens or does not soften; but in each case, the common basic purpose is to supply adequate safe potable water. The processes and procedures used at any one of these water works are the applications of previous investigations and research. Whether these are now totally adequate or acceptable to provide the qualities required in the finished water, must be continually assessed. Research to this end is therefore required.

The water authorities of the larger urban centres have of necessity been active in the provision of extensive laboratory facilities at their water works. Here, testing procedures have been supplemented by basic and applied research. The work of Howard and Thompson at the Toronto plants, Williams at the Brantford plant, particularly in the field of chlorination practices, and Matheson at Hamilton, are examples thereof. Men of this calibre have been prolific in their report and article preparation so that the water works field has been able to profit by their efforts. Their findings have been added to the mass of earlier information on water treatment. Many of these investigations contain the statement "other kinds of water may give other results". Therefore, all operators

should be aware that each water works is treating a water differing in some manner from any other and for that reason, research into the unique summation of conditions at the individual plant should be made by each operator.

It is becoming more evident that there is virtually no limit to the research which may be carried out at each water works plant. The processes that were being investigated earlier in this century are still not completely understood. Also, the need today appears to be more in dealing with industrial waste effects rather than the bactericidal problems that engrossed the early research teams; although virus contaminations and micro-organisms very definitely are still sources of concern. The long term effects on man of the exotic chemicals of the waste herbicides, pesticides, and fungicides are as yet unknown.

The waste chemicals arousing a great deal of interest at this time are the synthetic detergents, surface active agents or syndets. The commercial product is approximately 30% alkyl benzene sulphonate or A.B.S. while the remainder is usually a phosphate builder. Research is continuing on these waste syndets and to date, they do not appear to be in toxic concentrations but apparently interfere with co-agulation and sedimentation processes and may cause frothing at the taps. It may be that increased use of the new poly-electrolytes and polymers or activated silica will be needed with regular coagulants to achieve adequate results.

The associated phosphates are considered to be an excessive source of nutrient for the acquatic plants and algae.

With increased pollution, algae growths seem destined to become an increasingly severe problem. Taste and odour problems will then undoubtedly continue to be aggravated.

Studies and records of treatment processes, analytic methods, corrosion, algae, toxicity and associated operating costs, then are seen to be of prime importance.

CENTRALIZATION

Perhaps I have been able to indicate that the number of things requiring research are increasing rather than diminishing. A general awareness of this situation has been growing and with it a realization of the need for a central body to collect data, co-ordinate research and disseminate information. This centralization will assist in avoiding duplication of effort which would be wasteful of funds, personnel, and laboratory facilities which may be badly needed for other research activities. The facilities of the new OWRC laboratory and research station are singularly adaptable to assist in this role. These facilities and services are well described in the booklet provided to you titled "Ontario Water Resources Commission Laboratory Services". This programme will of necessity be a co-ordinated effort and the Commission looks forward eagerly to active participation particularly with the operators of all Ontario water works plants in this research programme.

THE OPERATORS' ROLE

But, you may say this is all very well for the laboratory trained operator with unlimited analytical facilities at his disposal, but what can the operator at the smaller plant achieve?

This is the almost-negative attitude that must be overcome. The need for applied research at all levels must be realized and a commencement of increased research thinking is needed, in particular to at least realize the problems at hand.

The small water works has an additional advantage since it allows plant scale experiments at a reasonable cost which cannot be done so readily in larger water works.

All research requires the collection of data. This is one reason that such emphasis, as described in Mr. Perry's lecture, is placed on the maintenance of proper plant records. When any alteration to plant or process is required or contemplated, quite often the planning period is not sufficient without the operator's recorded previous research, to allow proper assessment of the situation. Records of seasonal variations in supply conditions, disinfection and pumpages are probably the most important of these.

GROUND WATER PLANTS

In ground water systems, research into drawdown or the difference between static level and the dynamic or pumping level of the ground water should be made. Together with observations of the water levels of associated wells and test holes during this pumping, this data will be available for increased supply evaluations.

Changes in the static level may reveal depletion of the underground reservoir. A change in specific drawdown but with static level remaining practically constant, usually indicates

choking of the screen with sand and incrustations, less frequently, a damaged screen. The static level should be measured after long quiescent periods, preferably just before the commencement of the pumping cycle.

Samples of incrustations or accumulations of the bicarbonates and sulphates of calcium, magnesium, sodium and iron may be obtained from the walls of the discharge piping. These are usually removed from the well by acid applications. Research therefore, should continue at the water works or other laboratory to assess the incrustation problem and to recommend the proper acid for its removal. A drop in production with the static level normal may be due to a faulty pump of plugging of the well. The dissimilar metals of the pump may hasten the corrosion therein. Investigations here may save a pump from premature replacement. Research will determine if the iron bacteria which is now known as Crenothrix may become a problem and further investigations will be required to discover remedial measures including disinfection and/or removal of the nutrients by break-point chlorination.

Therefore, a complete physical, chemical, bacteriological and limnological examination is of prime importance. The information acquired will enable the intelligent installation of treatment to modify the undesirable characteristics of the water, will enable the operator to produce an acceptable water and finally, will enable industries requiring water for the industrial processes, to decide whether the supply in a minicipality is suitable for their purposes.

The present trend in water filtration plants is toward better treatment and to obtain this generally requires better pre-treatment methods, higher filtration rates, better coagulants and coagulant aids, improved filter design for operation, back-washing and control, shorter retention in treatment units, improved taste and odour control, more efficient scale and corrosion control, break-point chlorination, diatomite filtration, improved valving practices, increases in fluoridation practice, membrane filter techniques and cathodic protection of plant facilities.

COAGULANT AIDS

Interest is being shown in new instruments to measure the electrical potential or zeta potential on suspended particles in the raw water. These instruments are intended to assist in prescribing coagulant aids. The operator should be aware of the advent of such research aids.

The polyelectrolytes or coagulant aids which are usually complex synthetic organic compounds may be anionic (negatively charged), cationic (positively charged) or nonionic. These agents usually tend to improve the formation of a tougher floc which will settle more rapidly. The passage of increased quantities of organic material into the distribution system, due in part perhaps to syndet interference with coagulation procedure, may require process improvements with the aid of these polyelectrolytes. These are not equally effective on each water and therefore require research investigation at each plant. Advice on the acceptability and toxic potential

of each of these should be obtained before plant use is contemplated. However, an extensive programme of jar testing all the known polyelectrolytes and other coagulant aids with the water from each plant will rapidly expand the limited information available on these agents.

THE JAR TEST

The jar test probably allows the operator more insight into the complexities of water treatment than any other. Judicious investigations here can reveal the best kind and dosage of coagulant, coagulant aid, mixing and coagulating times and speeds, pH, and settling times. So it is of extreme importance that this phase of research and recording be extensively investigated. A proper stirrer of the Phipps and Bird type or equal is commonly used. Particularly, conditions in the jar test should be provided to emulate as nearly as possible, the conditions achieved in the process units. Due to the variance of conditions at each plant the test differs from plant to plant. Generally, however, it is accepted that a short period of rapid mixing is followed by a period of slower mixing and then a period of settling. This important test may ultimately have an associated standard form for comparison purposes. Williams has proposed alum stock solutions addition to 1000 millilitre raw water samples in 1500 millilitre breakers, rapid mix at 60-80 R.P.M. for 1-2 minutes, slow stirring at 30 R.P.M. for exactly 25 minutes and settling for 5 minutes. It can be seen that research by the operator can make this test one of his best control tools.

TURBIDIMETER

A turbidimeter, allows collection of further data on the water. The Jackson Turbidimeter is usually accepted as the standard for measuring turbidity but research by individual operators including Matheson has allowed them to acquire units most adaptable to conditions at their own plant.

As a result of many years' research with a particular raw water, the range of coagulant application most likely to produce optimum flocculation and sedimentation then, can generally be predicted by observing the magnitude and the trend of turbidity values and by conducting sufficient jar tests.

FILTERS

Filters and filtering medias are now receiving more basic research and the information on procedures at individual plants will assist in the co-ordinated reviews therein. Higher filtration rates in particular are expected. The operator should be making research into the effect thereof.

pH AND ALKALINITY

pH recordings of the raw and finished waters, together with total alkalinity determinations should be continually recorded.

SOLIDS CONTACT BASINS

It is considered that solids contact basins or upflow units will receive a greater degree of acceptance in the near

future. Those operators presently associated with such installations can assist the profession in its comparison of these with rapid sand filtration installations, by keeping extensive records of operating data.

TASTE AND ODOURS

Colour removal, disinfection and taste and odour practices should be expanded. The operator must be ever vigilant for taste and odours. This requires careful control, and systematic, continual sampling of the supply. The threshold odour test has been used extensively to ascertain the intensity of odours. Aeration, chlorine, chlorine and ammonia, chlorine dioxide, activated carbon, copper sulphate and ozone have been used to combat taste and odour problems.

Algae problems are expected to increase. Identification of the organisms is desirable and where trained staff is unavailable, submission of samples may be made to the Commission laboratory. Formaldehyde should be added to such samples to preserve them. Quantities and conditions at the time of the most severe concentrations should be recorded. Taste and odour tests at these times, together with filter run times and records of necessary corrective measures will aid in this evaluation. A microscope and descriptive illustrations will assist the operator in identifying such organisms.

Taste and odours have been attributed to all algae concentrations. As Mr. Neil will be giving you a lecture in this matter, I will not expand excessively on this but to say that other organisms associated with algae, such as actinomycetes in their

normal metabolism also give rise to serious tastes and odour problems. However, the algae and in some cases, the death of the algae serve as indices to possible taste and odour occurrences. For this reason algae identification should be undertaken at the plants together with a compilation of data to forecast lake turn-over, algae deaths etc. The threshold odour test at both 20°C and 60°C with an associated attempt to identify the taste and odour, will be required. Often, a fishy taste or odour is the advance warning of problems caused by actinomycetes.

American research has indicated that greater amounts of organic material is finding its way into the distribution system. Some of this material does not appear to be affected by biological oxidation nor can it be oxidized by chlorination. At present, the tools available for this research work consist generally of activated carbon filtration and chloroform extraction or the C.S.C.F.E.- chloroform soluble, carbon filter extract procedure. As yet, identification of these solids is difficult. It is reasonable to believe that as a nutrient or otherwise, this material can cause taste and odour problems in the system beyond the plant. In some areas a correlation has been observed between taste and odour intensities and outbreaks of intestinal enteritis. It would seem that the time is now ripe for each plant operator to commence research to assess the organic material reaching his own distribution system.

MEMBRANE FILTER TECHNIQUE

The comparative simplicity of the membrane filter technique for the bacteriological examination of water supplies has allowed it to be installed at a larger number of water works laboratories. Bacteriological examinations can be performed much more rapidly which allows a definite acceleration in disinfecting new mains and repairs. This research tool will also allow the operator to more readily assess the efficiency of his operations. This ease will be conducive to more frequent and intensive investigations at the plant.

CHLORINATION

Chlorination procedures are the safeguard of the water system and research here is always necessary. A trend toward break-point chlorination may be developing and the use of the amperometric titrator has increased. Research into the disinfection needs of his own plant will assist each operator in initiating any necessary modifications therein.

MEASURING AND RECORDING DEVICES

Telemetering is defined as the indicating, recording or integrating of a quantity at a remote point by an electrical translating means. The operator should familiarize himself with the advantages of measuring and recording devices and perform research on his plant to assess where these and telemetering can improve operations.

CORROSION CONTROL

Corrosion in the distribution system can be a source of severe complaint as well as causing a reduction in water distribution efficiencies. Where corrosive waters are corrected, calcium carbonate stability is usually attempted and the marble test together with Langelier's theory is the common index of water aggressiveness. A trend towards sodium silicate addition with pH corrections to values of 8.0 to 8.4 has been observed. Where necessary, operators could assess this treatment for their own plant by means of expendable iron samples, some of which can be inserted into the mains themselves.

FLUORIDATION

Where fluoridation of the water is practised, these operators should feel it a responsibility to assess their procedures and maintain adequate data thereon for later research appraisal.

CO-OPERATIVE APPROACH

As previously stated, the need for co-operative research under the guidance of a central authority is necessary to provide ultimate research benefits. The extended facilities of the OWRC laboratory and research station will assist such a central body and stand ready to assist the individual operator. But co-operative research is intended to mean just that, and the flow of data must be in two directions. The program can be most valuable if the operator becomes aware of the problems at his plant and takes co-operative steps with the research centres, to solve these problems.

The co-ordinated approach will allow other research centres in this country and abroad to deal with especially stubborn problems.

The Commission looks forward to a co-ordinated co-operative program of research closely synchronized with water utility personnel and other research bodies in Canada and abroad.

To obtain the maximum advantage, the water works operator will be required to think more often in terms of research, and the urgent part he can play in that program. This need is ever increasing and with the advent of improved facilities and co-ordination, his opportunities for research are greater today than at any other time.

ALGAE AND MICROSTRAINING

by

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An Address To
The Ontario Water Resources Commission
Basic Water Works Course
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ALGAE AND MICROSTRAINING

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INTRODUCTION

This lecture on Algae and Microstraining has been prepared to furnish the plant operator with a basic understanding of what algae are, the problems they create, and some discussion on the means available for their control. It is obvious that a life time could be spent on the study of any one of these topics without exhausting the problems for research so that in the hour available we will only touch on some of the principles and items of particular importance to the operator. In the demonstration period there will be an opportunity to observe some of these organisms. It is intended that later sections of this course will include more advanced information and some practice in identification and counting.

WHAT ARE ALGAE

Algae are plants just as trees and grass are plants. They are green, they manufacture their food in the form of starches or oils by using the energy of sunlight and the nutrients they extract from the water. In the classification of plants they are considered to be the most primitive group and some of the algae forms commonly found in water supplies are thought to be similar to the first life on earth. They are considered primitive because each cell is capable of carrying out the complete life history as no specialization has been developed into various tissues such as are found in the higher plants, i.e. stems, roots, leaves or seeds.

VALUE OF ALGAE

The Water Works operator often looks upon algae as purely a nuisance as it clogs filters, creates nusiances and imparts tastes and odours in the water supply. Algae are, however, the basis of all life in water. On land, grass feeds the rabbit which in turn is eaten by the fox and while the fox does not eat grass, there would be no foxes if there were no grass. This is called a food chain and at the basis of the food chain in water, is algae. This plant feeds minute animals that are in turn eaten by minnows which in turn provide the food for pickerel. Thus, if there were no algae there would be no pickerel. It can be demonstrated that fish production in a lake varies directly with the amount of algae that it produces and thus while it may be a disadvantage in a water supply, it is not unnatural and is a necessity for other uses we make of water. When the first men start making long distance trips into space, the food they will live off will be algae grown in the space capsule.

SIZE AND DISTRIBUTION

There are several thousand different species of algae that live in the waters of Ontario. These range in size from a plant as much as four feet tall down to cells which are so small that they can barely be seen when magnified a thousand times in a microscope. Algae live in almost any place where there is moisture and sunlight. In addition to living in the oceans, lakes and rivers down to the depth where the light can penetrate, they also live on the damp soil on the face of glaciers, and in combination with fungi to produce the lichens we are all familiar with.

GROWTH REQUIREMENTS

Algae are very specific in their needs. The types that are characteristic of lakes are seldom found in streams and those which populate a lake in summer give way to other forms in winter. Some species can only live in very pure water and others are obligated to polluted situations and even sometimes to particular types of pollution. Factors governing the type and number of algae are environmental such as temperature, available light, nutrient concentration, and so on. No two species have exactly the same requirements.

ALGAE PROBLEMS IN THE OPERATION OF WATER SUPPLIES

The operator can be faced with problems created by algae of several kinds. In all cases, they result from an over-abundance but the numbers required to create this difficulty will vary.

FILTER CLOGGING

The reduction of filter runs, caused by the coating of the surface of the filters with large numbers of these minute plants is probably the most common and serious problem that algae create for the Water Works operator. Certain waters at certain times of the year produce a great abundance of the filter clogging species and under the worst conditions may reduce the production of water through a filter to a point where there is hardly sufficient to back wash it. The lake diatoms are the most common trouble maker in this regard but certain of the summer blue-green algae will also develop in sufficient numbers to reduce filter runs.

The obvious way to solve the problem of short filter runs is to remove the algae before they get to the filter. The common method of removing algae from raw water is the use of settling basins which may include flocculation and pre-chlorination. Microstrainers are also being used to remove the algae before the water is filtered. A third method is to apply algicides to the raw water and thus remove them before the water enters the plant.

The principle of removing algae by flocculation and sedimentation involves trapping the algae cell in the alum floc and carrying it to the bottom with other unwanted solids from the water. When algae populations are very high they often hold the floc in suspension long enough for it to pass through the settling basins and onto the filters. This floc and the algae can be settled if weight can be added to the floc. A slurry of ordinary clay mixed and fed during the periods of difficult times will do much to get the operator over a short term period of difficulty. Increased dosages of alum and heavier pre-chlorination will also assist in alleviating short filter runs.

Where short filter runs create a chronic problem or where the capacity of a plant is limited by high algae populations at certain times of the year, microstraining can be used to remove most of the algae before the water reaches the filter. This and chemical treatment will be discussed more fully later in this talk.

ALGAE AND TASTES AND ODOURS

Algae are capable of producing tastes and odours that will persist through treatment and cause consumer complaints. The whole subject of tastes and odours is the subject of the next paper but perhaps a little repetition will be of value.

There is much published information on taste and odour problems caused by algae. Different algae have been shown to cause different flavours and odours that have been variously described as pigpen, grassy, musty, cucumber, etc. While there is no doubt that these problems do occur it has been observed that in this province most of the difficulty does not come from algae but is the result of the decomposition products of the rooted aquatic weeds. Raw water supplies that come from shallow weedy lakes almost invariably have a continuous or intermittent problem with tastes and odours. This problem is usually most acute late in the fall when the ice cover is first formed and again in the spring at the time of the break-up of ice cover.

Two methods are commonly used in controlling tastes and odours: one, the feeding of activated carbon and two, variations in the method of chlorination. Activated carbon is the only sure method of taste removal, but this on a continuous basis is somewhat expensive. The use of chlorine dioxide or chloramine at various points of application in the plant may assist in controlling tastes and odours but this is an individual problem with each Water Works and can only be determined through experimentation.

One of the common sources of tastes and odours to a water treatment plant is the decomposition of accumulations in the settling basin. A number of instances have been observed where water leaving the treatment plant was in poorer condition than in the raw water coming in. A short term routine in cleaning settling basins should be practiced by all Water Works in order that the decomposition products from the accumulated solids do not impair the quality of the water.

GROWTHS IN RESERVOIRS

A third common problem that algae create in Water Works operation is the growths in reservoirs. Here the algae may grow attached to the walls where they form a heavy mass of material alive with crustaceans and insect larvae. Or it may be the free floating type similar to that removed at the filtration plant. Either one may impart tastes to the water and the odd little animal that comes through the taps, may shake the confidence of the consumer in the purity of the supply. Probably the most common algae causing difficulty in reservoirs is one of the large species called Chara. This algae grows to a height of two or three feet in a soft mud bottom and is typical of the cold hard water commonly found in spring water sources. Where such water is collected and stored in an open reservoir this algae invariably grows and is difficult to control.

CONTROL OF ALGAE

There are two basic means of controlling algae and solving the problem that they create: one, by controlling the environment in such a way as to make it an unsuitable place for them to live, and two, by killing them with chemicals. The latter method is less satisfactory in the long run as it necessitates adding chemicals that are costly on either a continuous or intermittent basis. Controlling the environment is a more satisfactory means though this is not always possible.

ENVIRONMENTAL CONTROL

The exclusion of light is probably the most common environmental control. The easiest method is simply to cover the reservoir although this is often not done and algae problems continue year after year. A second method of reducing light is to use activated carbon to induce an artificial turbidity. While this is only a temporary measure and must be repeated every few days it has the added advantage of absorbing taste and odours from water while in suspension and keeping the bottom accumulations sweet. Carbon can only be used in the raw water where the treatment following includes good sand filtration. Another method of excluding the light would be covering the reservoir with black plastic. While this has not been used it would be effective in excluding light and be relatively inexpensive and easy to apply.

The regulation of algae growth by controlling the nutrients is not always possible though effective where it can be applied. In choosing a new supply care should be taken to utilize water of low fertility as judged by chemical analysis and the algae population that it maintains. In this case a limnologist should make several inspections at various times of the year to determine the numbers and kinds of algae present and to assess the suitability of the water. Where the municipality controls the land adjacent to the supply, care should be taken to keep out surface drainage and other possible nutrient sources. Run-off from farm buildings, domestic sewage and certain industrial wastes are rich in plant nutrients and should be avoided as only small amounts of these fertilizing substances can induce the development of high algae populations.

CHEMICAL CONTROL

While there are many algicides sold today, only two are suitable for use in a domestic water supply, namely copper sulphate and chlorine. The cheapness and availability of copper sulphate and its safety from a public health standpoint makes it the most satisfactory chemical to use. The effectiveness of copper sulphate varies somewhat with the chemical composition of the water. In hard water the copper precipitates rapidly and thus more is required than in soft water. As a rule of thumb, 015 ppm. will kill most organisms in surface waters. Copper sulphate is very toxic to fish and 0.5 ppm. is about all they will stand. Chlorine is sometimes used as an algicide especially where water is taken into a holding basin. A residual of 1.ppm. will kill most algae forms. While chlorine is more expensive than copper its use is understood by operators and equipment is usually available for feeding it.

In applying chlorine, a rough calculation must be made of the volume of water being treated and the pounds of chlorine required to satisfy the demand and still provide a residual of 1. ppm. The calculation is used as an initial guide, then followed by chlorine tests to provide the final adjustment. A similar calculation must be made for determining the amount of copper sulphate but more care must be exercised as no simple test can be used as a guide. To do this, the surface area of the water to be treated must be obtained together with the average depth of the water. When multiplied these two figures give the volume of water in cubic feet. The total number of pounds of water may then be calculated by multiplying the volume by 62.3. As one part per million (ppm) equals 1 pound per million gallons, the treatment of a reservoir with 0.5 ppm. would require one half a pound for each million pounds of water.

Area x Average depth x 62.3 - lbs. of water in reservoir

1 ppm. - lb. per million lbs of water

Copper sulphate is sold in a variety of crystal sizes. The method of application varies with the grade of crystal used. In general, the finest crystals may be distributed on the surface of the water as they will immediately dissolve. Larger sized crystals may be dissolved in water and pumped as a spray or they may be put in a burlap bag and towed through the water in such a way as to provide an even distribution of the calculated amount of chemical over the entire surface of the reservoir. The operator must know the depth of water as he applies the chemical and see that the deeper water receives proportionally more chemical than the shallow areas.

The ideal time to apply chemicals is when the algae population is rising but before the condition becomes acute. If treatment is postponed until a very dense growth of algae occurs the sudden killing of this material and the subsequent decomposition may remove all the oxygen from the water causing it to go septic, kill the fish, and become foul tasting. If the condition gets out of hand before treatment can be applied half the reservoir should be treated first, to reduce the population, and after a week or so has been allowed for this material to decompose the total reservoir area can then be treated.

MICROSTRAINING

Microstraining as a method of water treatment has been introduced into Ontario within the past five years, and there are now five installations operating on municipal water supplies. The development of this means of filtration was made possible by the invention of an extremely fine wire mesh capable of removing such small particles as algae from the water and yet capable of passing high volumes of water. The principle of the microstrainer is simply a rotary screen where the raw water is fed to the inside and flows out through the screen material. The drum is about three quarters immersed and as it turns around, a jet of water played on the surface of the screen knocks down the accumulated solids into a hopper and from there are carried to waste.

In water treatment the microstrainer has two uses: (1) as pretreatment for algae removal ahead of conventional sand filers, and (2) as sole treatment for waters for the removal of algae and

other extraneous material where turbidity is not a problem. It has been our experience that they have proven very effective in extending the operating time of conventional sand filters during times of heavy algae blooms. In one instance, runs of not less than 20 hours have been obtained where previously 6-hour runs in summer were not uncommon and as little as two hours were experienced. Where this equipment is used as a sole means of water treatment it should never be installed with the thought of reducing turbidity. Where it has been used solely for the removal of algae and the protection against the variety of water fleas, insect larvae, leeches and aquatic worms, that commonly pass through unprotected water supplies, it has been found to be very satisfactory.

OPERATION

Some of the microstrainers installed in the province have been set up on an automatic control system and some are operated manually. The system used will depend on the individual plant. In general, they are easy to operate and require only the normal lubrication and an occasional wash down. Over a period of time some permanent plugging of the screens will take place that is not backwashed by the water jet. When this occurs, the strainer must be drawn down and a 12% sodium hypochlorite solution applied directly to the fabric while the screen turns over slowly. It should be emphasized that concentrated chlorine solutions from a chlorinator or from chlorine powders are not effective in rehabilitating the screen capacity.

The reason for the sliming of the fabric is not well understood. The time between washings has varied anywhere between one day and six months and in one or two instances difficulties due to lessening of filter capacity over a period of one or two days has occurred. In all cases, the screens have been quickly rehabilitated with the hypochlorite wash and an investigation is now underway to obtain a continuous method of protection against this short term loss of capacity.

WATER MAIN INFESTATIONS

While water main infestations do not necessarily come under the title of this paper, there has been considerable interest in this matter in the past year, and so perhaps a little of the fact and fiction should be separated.

It is probable that most if not all water distribution systems contain living organisms of some kind. A brief survey of the literature indicates the wide variety of animals that have caused difficulty from time to time. These have included nematodes, aquatic earth worms, snails, clams, a variety of aquatic insect larvae, leeches, Gordian or horse hair worms, Daphnia or water fleas, etc. Many of these have occurred in municipal supplies having complete treatment of flocculation and sand filtration. The method of entering the distribution system often remains a mystery though in many cases it is thought that the minute egg passes through the sand bed and develops subsequently in the distribution system. This problem is not more widespread because the inside of a water main is relatively clean so that food is available only in very limited quantities. In some cases the life

cycle cannot be completed entirely under water so that insects such as blood worms cannot reproduce in the water main.

NEMATODES

Earlier this year an article on worms in the drinking water in a leading U.S. News magazine aroused the public and many inquiries were directed towards this organization and undoubtedly the municipalities.

The worms referred to were round worms or Nematodes. These are a very small animal barely visible to the human eye. Some authorities consider them to be the most numerous animals on earth as they are found in the soil on lake bottoms, along the shores, in sewage sludge and in fact in almost any sample of earth. In view of their great numbers, it is not surprising that a few of them find their way into water distribution systems. Here they are able to subsist on the thin coating of slimes lining the water main and in organic depositions in low flow sections of the distribution system.

In this country, Nematodes have no public health significance, they carry no diseases, and are not human parasites. Although it is not likely known, many of the Nematodes are consumed by an individual every year in raw fruits, salads, vinegar, and perhaps even in his drinking water. They are quite resistent to chlorination and the levels normally applied for the control of pathogenic bacteria are not sufficient to kill the nematodes. In this respect, we are fortunate as this climate controls some species that are a serious human problem in the middle east and Asia.

CONTROL OF INFESTATIONS

As most of the organisms that inhabit water mains are resistent to normal Water Works sterilization procedures and as no chemicals are suitable for adding to water to control this type of nuisance organism, good housekeeping is the only effective control. As much as possible of the organic material should be kept from the water mains. This is best accomplished through chemical precipitation and sand filtration. In laying water mains low flow areas should be eliminated as much as possible, as these provide a refuge, and where dead ends occur they should be flushed routinely. In this way, it will be possible to maintain the confidence of the consumer in the products that you deliver.

CONCLUSION

This lecture has only touched very lightly on the high spots of this subject. Future courses will provide further and more detailed information. In the meantime, for those interested in learning more of this subject, a book recently published by the United States Public Health Service is well worth your reading and cannot be too highly recommended. The title is Algae in Water Supplies, by Mervin C. Palmer. It is available from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. for the price of $1.00.

As the operator can hardly be expected to be a competent Biologist, Chemist, mechanic and gardener, problems and identification of unknown organisms arise from time to time. It is the intention

of this laboratory and certainly the Biology Section to assist wherever possible. In this regard, consultative and identification services are available and provided to the limit of the capabilities of our small staff. If specimens such as insects, algae, etc., are to be sent for identification, it is important that they be preserved. Formaldehyde is cheap and effective and can be purchased from any drug store. If the sample is put in a solution of about 5% formaldehyde and 95% water, it will be assured of arriving in good condition.

TASTE AND QDOUR CONTROL

by

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An Address To
The Ontario Water Resources Commission
Basic Water Works Course
Toronto, Ontario
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TASTE AND ODOUR CONTROL

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HISTORY & IMPORTANCE

The reaction of consumers to an odorous or bad tasting water is generally immediate, volatile and creates in their minds grave doubts about the competence of the water treatment plant staff. If the problem occurs frequently or is long lasting your public relations deteriorate. These factors and your own desire to produce a quality product make it imperative that you make every effort to successfully control all taste and odour problems.

Efforts to improve taste and odour and appearance of water long out date the development in making water supplies safe. Some of the first developments in this regard was the introduction of filters in the early 1800's and aeration in the middle 1800's.

At the beginning of this century algae were considered the principal source of taste and odour and one of the first methods of control was the use of copper sulphate.

Our recent industrial development has led to new more complex wastes with their subsequent taste and odour problems.

The introduction of chlorine and allied compounds in the early part of the century and later carbon has been stimulated and advanced by the necessity of controlling these new taste and odour problems.

TYPES & CAUSES

(1) Tastes

There are four fundamental types:

Sweet
Sour
Bitter
Salt

The other apparent forms are due to the fact that taste is associated with the simultaneous effect of smelling.

(2) Odours

Unlike tastes there is much uncertainty as to the number of odours and as to how these types should be classified. The following is one method of classification:

Odour types	Description-Such as odour of -
Aromatic (spicey)	
Cucumber	Camphor, cloves, lavender, lemon
Balsamic (flowery)	
Geranium	Asterionelle
Nasturtium	Aphanizomenon
Sweetish	Coelosphaerium
Violets	Malbomanas
Chemical	
Chlorinous	Free chlorine
Hydrocarbon	Oil refinery waste
Medicinal	Phenol & codoform
Sulphuretted	Hydrogen sulphide
Disagreeable	
Fishy	Uroglenopis & Dinobryon
Pig pen	Anabena
Septic	Stale sewage

Earthy	
Peaty	Damp earth peat
Grassy	
Grassy	Crushed grass
Musty	Decomposing straw
Musty	
Moldy	A damp cellar
Vegetable	Root vegetables

TESTS

Taste tests can be performed on water known to be safe. In most cases the odour test will be sufficient, but there are a few tastes not readily detected by the odour test.

(1) Taste

The taste test should be made at the natural temperature of the water (about 20°C) and at about 60°C. This test can be made on the various dilutions before making the odour tests.

(2) Odour

There is no absolute odour value. Different people react differently to a given odour concentration and even the same individual may report a different intensity for a given concentration of an odiferous substance at different times.

(a) Threshold Odour Test

This requires the diluting of a sample with odour and taste free water in different proportions. The threshold point is the greatest dilution in which the odour is just detectable. A convenient way of expressing the results is the dilution number. For instance, if the first detectable odour occurred when 25 ml. of sample was diluted to 200 ml., the number is 8, i.e., 200 ÷ 25. For full details on carrying out this test see Standards Methods for the Examination of Water and Waste.

Panel results are more meaningful since individual differences have less influence on the results. The temperature of the sample should be recorded. The test may be conducted at $20^{o}C$ (cold odour quality) or $60^{o}C$ (hot odour quality). The higher temperature is preferred as it will enable the operator to detect odours far below the level which will be noticed by the average consumer.

SOURCES OF TASTES & ODOURS

(1) Weeds

Generally speaking they do not impart any characteristic natural odour, but may produce a vegetable taste and a disagreeable odour due to decomposition.

(2) Plankton

Among the plankton organisms in water are; bacteria, yeasts, protozoa, rotifers, microcrustacea, algae and actinomycetes. The most troublesome of the nuisance organisms are the algae and recently many taste and odour problems have been attributed to actinomycetes.

(a) Algae

The majority are microscopic but they reproduce in such large numbers that they produce readily visible masses. The chief offenders are diatoms, blue green algae and pigmented flagellates.

(b) Actinomycetes

The actinomycetes along with the viruses form a border line system between the living and the non living bodies, but on a much more specialized scale. They are considered by some as a higher type of bacteria and by others as a lower fungi. Actinomycetes are placed in a group by themselves with some properties of both. They usually start from spores and are active from early spring to late

fall. They give a grassy or fishy taste.

(3) Microscopic Organisms in Distribution System

Iron bacteria are some of the most important fouling organisms found in a distribution system. Some bring iron into solution, others cause its precipitation and in certain instances are responsible for corrosion. Also, sulphur and sulphate reducing bacteria are important as they produce sulphide which is dissolved in water and produces the characteristic hydrogen sulphide or rotten egg taste.

(4) Industrial Waste and Sewage

Tastes and odours can be caused by the following types of industries; dyes, medicinals, plastics, steel, and canneries.

Biological growths and the presence of sewage which will increase the growth rate and possible tastes and odours. In addition, some of the components of domestic sewage such as detergents will produce tastes and odours.

(5) Chlorination

The natural odours of water are frequently intensified or changed in character by the use of chlorine as a disinfecting agent. The odours caused by the use of chlorine or chlorine compounds as disinfecting agents may be attributed to one or more of the following causes:

(a) Excess free residual and combined chlorine.

(b) Destruction of organisms resulting in the release of aromatic substances which in some cases unite with chlorine.

(c) Substitution compounds of chlorine with phenolic compounds.

CONTROL METHODS

(1) Activated Carbon

(a) General

Activated carbon is the most widely known method for the control of taste and odour. This material possesses very high adsorptive characteristics and actually removes the objectionable materials from the water. Excessive doses of carbon will do no harm unless filters are in a condition which permits passing of the carbon. Besides controlling tastes and odours, carbon helps to stabilize sludge, improve floc formation and remove non odour causing organics thus reducing the chlorine demand of the water.

(b) Dosage

The simplest method is by gradually increasing the dose at regular intervals and measuring the resultant effect by frequent threshold determinations. The minimum dose required is that which just reduces the threshold odour to the desired value.

An alternative to the above is to add varying amounts of carbon to portions of sample and try to duplicate plant treatment on pilot basis. This can be done by stirring, settling, filter through odourless glass wool and subject filtrate to threshold odour test. The percent odour remaining is plotted against total odour removed per unit weight of carbon at each dosage. This should produce a straight line curve on double logarithmic paper. Such a survey can be extended to any desired residual odour.

(c) Points of Application & Feeding

Flexibility of operation is quite important as tastes and odours vary widely at different times and require extraordinary treatment only for short periods. For this reason wide range chemical feeders are essential. Dry feed and slurry feed are the methods in use for applying carbon. Slurry feeding offers easier and cleaner operations than does the dry feed method. Slurry feeding assures that the carbon is thoroughly wet which is important for maximum effectiveness of adsorption.

The points of application will vary with local conditions. Carbon may be applied to the raw water, mixing basin, flocculating equipment, sedimentation basins or ahead of the filters. Although adsorption of carbon is instantaneous a contact period of 5 to 30 minutes is helpful.

Carbon adsorption is most effective at the lowest pH value of the raw water. Therefore, it should be added ahead of any softening process where the pH is raised. In addition, chlorine is adsorbed by carbon. For this reason the carbon should be applied at least 5 to 15 minutes ahead of the chlorine.

(2) Aeration

The general view is that aeration will only reduce odour concentration by 10 to 20% unless they are extremely volatile such as hydrogen sulphide and sewage type odours.

Aeration can be accomplished by any method of exposing a maximum water surface to the air, i.e., by fine bubbles, splashing the water in thin sheets over weirs or baffles or discharging the water so that it falls freely through the air.

(3) Chlorine Ammonia Treatment

(a) General

Chloramines have been in particular successful with phenol tastes. The mechanism of the process lies in the low oxidation potential of chloromines and in the slowness with which they react to form chloro substitution products. Thus the objectionable tastes and odours are not formed or are formed only slowly.

This material is effective in preventing tastes and odours not in removing those that are already present.

(b) Dosage

The ammonia may be added in the form of a gas, in which case equipment similar to a chlorinator is used, or as an ammonium salt. In the latter case it should be added as a solution. Dry feeding is not successful since it does not ensure complete solution and the required accuracy of dosage is not obtained.

The ratio of ammonia to chlorine most frequently employed is 1:3 by weight although this varies considerably from plant to plant. From our own experience the chlorine should be slightly in excess of the theoretical limit. This will ensure that all ammonia is combined and will not have any to serve as nutrients for aquatic growths.

(c) Point of Application

It is esential that the ammonia be added first and intimate mixing provided beforethe chlorine is injected. This provides for the

immediate formation of chloromines before the chlorine has had an opportunity to react with organic matter or other substances. The interval between the addition of ammonia and chlorine should not be too long or oxidation of the ammonia to nitrate and nitrite may take place. Five minutes should be sufficient with proper mixing.

(4) Free Residual or Break Point Chlorination

(a) General

This process is the application of chlorine to water to produce directly or through the destruction of ammonia or nitrogenous organic material a free available chlorine residual. This residual is maintained through all or part of the plant or distribution system. Free chlorine residual includes elemental chlorine, hypochlorous acid (HOCl) and hypochlorite ion ($O\ Cl^-$) and may be measured by the standard orthotolidine arsenite test. The break-point process is a refinement of and should be regarded as a phase in superchlorination treatment.

(b) Illustration of Break-Point Curve

(c) Dosage

It is usually found that the tastes reach a minimum at a point just beyond the break-point. Sometimes, however, all taste are not removed or a slight musty odour remains. Some tastes which are removed or nearly removed at the break-point may be intensified by superchlorination. In such cases the application of a little activated carbon is effective.

(d) Points of Application

A contact period is required for break-point or superchlorination. An average minimum is 2 hours and an average maximum is 5 hours. For this reason and to prevent odour penetration to the

plant facilities this treatment should be instituted in the raw water.

(5) Superchlorination and Dechlorination

(a) General

Superchlorination is the term commonly used for the application of chlorine at high dosages to increase the rate of reactions. This practice results in excessive amounts of free residual chlorine and the water must undergo dechlorination before it is drunk.

The same general notes can be applied as indicated for the break-point process. Dechlorination is accomplished by adding a reducing agent such as sulphur dioxide, activated carbon or aeration.

(b) Break-Point vs. Superchlorination

The advantages of break-point chlorination are:

(i) dechlorination is not necessary

(ii) less chlorine is required

(iii) the taste is usually at a minimum at or beyond this point.

The advantages of superchlorination are:

(i) where the organic content of the water is high or fluctuating this ensures that the dose does not fall below the break-point.

(ii) where the period of contact is short the increase chlorine concentration may increase the rate of reaction.

(6) Chlorine - Chlorine Dioxide

(a) General

This process usually involves the application of chlorine dioxide to waters previously treated with chlorine. The combination is used rather than chlorine dioxide alone to reduce costs and

utilize certain advantages of chlorination such as a known bactericidal effect.

This material has been employed to control algae tastes, phenolics and other industrial pollution tastes.

(b) Dosage

Under normal temperature and pressure conditions, chlorine dioxide is a reddish yellow irritating gas. Because of its instability, chlorine dioxide cannot be shipped or stored in bulk, but must be generated in relatively low concentrations at the point of use.

It is made by the action of chlorine on sodium chlorite

$$2\ NaClO_2 + Cl_2 \text{ --- } 2\ ClO_2 + 2\ NaCl$$

To ensure completeness of reaction an excess of chlorine is employed. The theoretical ratio is 1 part chlorine to 4 parts chlorite. The usual recommended ratio is 1:2. The pH has a significant effect on the efficiency of reaction. Above a pH of 5.5 there is a poor yield of chlorine dioxide.

There is no simple test for chlorine dioxide. The dose is controlled by accurate feed and partly by the attainment of a greenish yellow colour in the liquid in the reaction tower.

Work done at Lindsay on a musty fishy tank taste demonstrated that only a low concentration of chlorine dioxide was required, i.e. 0.5 ppm, any excess had no further effect on the taste. This makes control easier in a supply with a fluctuating taste. All that is necessary is to set the dose at the highest required as the excess produces no problem.

(c) Points of Application

At Niagara Falls, New York, the rate of reaction was only a few seconds, whereas at Lindsay a long contact period was required. The usual procedure is to pretreat with chlorine for disinfection and post treat and odour control. However, this should be judged by results obtained.

(7) Watershed Control

This is a preventative type treatment and is usually concerned with algae. The chief factors which encourage algae growths in water are:

(a) exposure of water to sunlight
(b) clarity of water, allowing deeper penetration of light
(c) stagnation of water
(d) nutrients such as silica, phosphates and bicarbonates
(e) moderately high pH values, i.e., neutral to faintly alkaline.
(f) suitable temperature

Control can therefore be exercised by regulating the above requirements. In some cases algicides such as copper sulphate, carbon or chlorine can be used to advantage. The dosage and time of dosage should be discussed with Mr. Neil of the Commission.

SUMMARY

Activated carbon is the most versatile of the agents used, but for persistent odours it may take such a quantity that other methods might be preferred. Many plants do not use activated carbon because of a dislike for handling it. Other plants do not use it because of a lack of facilities, e.g., no sedimentation or filtration.

Each plant and each odour and taste is a problem of its own and hence preliminary experimentation is necessary.

The following table was extracted from a study made by Sigworth ("Control of Odour and Taste in Water Supplies" J.A.W.W.A 49:1507 Dec. 1957) of 241 plants in the U. S. reporting problems with taste and odour. The overall summary indicates that activated carbon was successful in 86% of the cases used followed by chlorine dioxide with 25%. The least effective was aeration.

DEGREES OF SUCCESS WITH CORRECTIVE TREATMENT

ALGAE

	Percent of success reported* Total	Partial	None
Activated Carbon	90	9	1
Free Residual Chlorination	13	44	42
Super- and Dechlorination	24	41	34
Chlorine Dioxide	13	25	62
Aeration	11	53	36

DECAYING VEGETATION

Activated Carbon	92	7	1
Free Residual Chlorination	16	43	41
Super- and Dechlorination	30	25	45
Chlorine Dioxide	14	19	67
Aeration	6	47	47

INDUSTRIAL WASTES

Activated Carbon	68	28	4
Free Residual Chlorination	19	35	45
Super-and Dechlorination	17	33	50
Chlorine Dioxide	49	24	26
Aeration	14	43	43

OTHERS

Activated Carbon	87	9	4
Free Residual Chlorination	28	31	41
Super- and Dechlorination	20	30	50
Chlorine Dioxide	14	10	76
Aeration	7	50	43

OVERALL SUMMARY

Activated Carbon	86	12	2
Free Residual Chlorination	17	41	42
Super- and Dechlorination	23	34	43
Chlorine Dioxide	25	31	54
Aeration	9	49	42

* Percentages are based only on those plants that reported having tried that specific treatment on the particular cause of odour and taste.

DISINFECTION OF WATER SUPPLY FACILITIES

by

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District Engineer - OWRC

An Address To
The Ontario Water Resources Commission
Basic Water Works Course
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DISINFECTION OF WATER SUPPLY FACILITIES

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INTRODUCTION

The disinfection of water handling equipment, newly constructed or repaired, must be effected before such appurtenances contact potable water. Disinfection is required to protect the health of the consumer and prevent various water supply nuisances. The subject will be handled under two general headings:

(a) Disinfection of Equipment Before Service

(b) Disinfection of Operating Equipment.

DISINFECTION OF EQUIPMENT BEFORE SERVICE

GENERAL

Before placing equipment, which is to contact potable water in service, it should be thoroughly disinfected. The efficiency of this step is of great importance where unchlorinated supplies or large distribution systems are concerned. Where the chlorine residual of the contacting water is zero, or very low, the potable water could be re-infected in improperly sterilized mains. Appurtenances close to a chlorinated source may actually be disinfected by routine chlorination. Nevertheless, this type of disinfection is not fully assured and therefore not a substitute for pre-disinfection.

Disinfection is carried out for two reasons. The first and main reason is for the destruction of pathogenic micro organisms. A second reason is for the elimination of non pathogenic micro organisms that can cause colour, odour, and taste problems.

PIPE LINE DISINFECTION

Pipe Cleaning

Chlorine is considered as a surface contact disinfectant. Therefore, the area to be sterilized must be clean. During construction, the pipe should be kept dry, and a tight fitting plug provided at the end to keep out foreign matter. Lengths of pipe having soiled interiors should be cleansed before use. One method of removing stray clumps of soil and other debris during construction is to drag a brush made by bunching sufficient mop heads, by a rope through the pipe, keeping a length or two behind the end.

Never leave an open pipe end unattended. Small animals have been known to crawl inside a main and have become trapped. If they are jammed against a valve or constriction it may be necessary to remove several lengths of pipe to free the main of the dead animal.

If ground water is a problem in the trench, a water tight plug should be inserted in the pipe end. The ground water will carry mud and it may be contaminated by sewage from severed laterals. If allowed in the pipe or main it will leave a layer or coating of material in the bottom of the pipe. In such a case, several attempts may have to be made to disinfect the main.

Before disinfection is attempted, the repaired or new main should be thoroughly cleaned. This is effected by opening available drains and hydrants until the water runs clear.

A velocity in the main of 3 f.p.s. has been suggested as a desirable minimum during the flushing. All ends must be flushed in this programme.

Disinfection

The usual disinfectant in the water works field is chlorine. This can be obtained in many forms, HTH 70% (calcium hypochlorite), HTH 15%, liquid sodium hypochlorite, and in the pure gaseous or liquid state. The form of product chosen will depend on the size of job and the equipment available. The most economical form, not considering dispensing costs, is the pure liquid or gas product. In new water works systems equipped with gas chlorinators, the distribution system could be economically disinfected using the gas product. On repaired sections and isolated additions the installation of gas equipment is seldom economically possible. The liquid solution application of other forms of chlorine is then used. The greatest percentage of main disinfection is effected using hypochlorite products.

The chlorine strength required for disinfection varies with time. For 24 hour retention a 50 ppm chlorine residual is recommended. When the disinfection carrier has a high chlorine demand this must be allowed for to ensure an adequate residual. A half hour retention period would require a 150 ppm application.

SAMPLE CALCULATION

Pipe Line = 1 mile of 8 inch main
= 11,500 I. G. liquid volume

Chlorine required for 24 retention

$= 50 \text{ ppm} \times 11{,}500 \times 10^{-5}$
= 5.75 pounds of chlorine

HTH 70% required (allow 25% loss)

$$= \frac{5.75 \times 10^4}{70 \times 75}$$
= 11.0 pounds of HTH 70%

sodium hypochlorite, 10% solution (allow 25% loss)

$$= \frac{5.75 \times 10^4}{10 \times 75}$$
= 77 pounds or 7.7 I.G. of 10% solution.

The disinfecting solution is added as the flushing water is displaced. The various end valves and hydrants are operated until the chlorine residual shows. The flushing is started near the feed source gradually working towards the ends. An even disinfectant application is necessary. The solution can be fed to the main near the filling valve via a corporation cock. The chlorine residual can be determined by using litmus paper or orthotolidine testing solution. Using the O.T. test a deep red colour will indicate a strong chlorine residual but for more accurate determination a dilution method will be required to bring the O.T. test below 1.0 ppm.

Various liquid solution feeders and injectors are available for applying disinfectant. Large municipalities should have such equipment on hand while small municipalities must rent or borrow the necessary feeders.

The practice of leaving HTH tablets in the main during construction so that the necessary chlorine residual is obtained when the system is flooded should be used with care. This method of disinfection prevents prior flushing and cleaning. When the lines are filled all tablets may be washed to the far end. The tablet method of disinfection might be satisfactory on small sections of main.

For effectual disinfection the packing must be free from contamination. Jute is best disinfected by spreading it out on a clean floor and dusting on HTH powder. Soaking in 1% available chlorine solution is satisfactory, provided the fibers are dried before ramming in the joint.

Bacteriological Tests

After disinfection the strong chlorine solution is flushed to waste and bacteriological samples are collected. Do not test until the chlorine residual is zero or at the level of the normal treated water. When satisfactory test results are obtained the system may be placed in service. Further samples should be collected when the mains are in use to confirm the effectiveness of the disinfection programme.

STORAGE TANK DISINFECTION

As with pipelines the storage tank must be cleaned before disinfection is attempted. All dirt, scale, and other loose material must be removed.

Disinfection can be accomplished by spraying a strong 250 ppm chlorine solution on cleaned surfaces. In using this method make sure the tank is adequately ventilated before entering. Wear a mask with an outside source of air, such as a bottled air supply, and protective clothing during the work, including goggles.

A second method of disinfection which is satisfactory for small tanks is to fill the tank with a 50 ppm chlorine solution. In sterilizing pressure tanks make sure that all air is removed so that all surfaces are contacted. The retention time as in the case of pipe lines is 24 hours. The strength could be reduced if a longer retention period is utilized. Untouched wall surfaces above the water line and ceilings should be brushed with a strong chlorine solution.

Bacteriological samples are collected when the sterilizing solution has been fully removed. The chlorine residual should be zero or that of the supply. As per the pipe lines the tank contents should be sampled from time to time.

DISINFECTION OF WELLS

Equipment contacting a potable water; pumps, casings, drop pipes, and other well appurtenances; must be disinfected before being placed in service. As well water is seldom chlorinated on a routine basis the primary disinfection is most important.

Before installing drop pipe and pump, remove all surface mud and debris. When pump is installed, apply a chlorine solution to obtain a 50 ppm chlorine residual in the well. Operate pump to obtain a strong residual at the end of the newly constructed distribution feed line. Where a long line is involved, add chlorine solution slowly while pumping to well. Retain the heavy solution in system for 24 hours.

It is advisable to return the heavily chlorinated water back down the well between the casing and drop pipe, when applicable, during the first 30 minutes of pumping, to wash down and disinfect the inside of the casing insofar as possible.

Adverse bacteriological tests should be followed by redisinfections. Continued adverse tests may be attributed to ground water contamination and not contamination by well equipment.

DISINFECTION OF OTHER APPURTENANCES

Meters, short lengths of pipe, valves, and other appurtenances, can be disinfected with a one percent chlorine solution for a short contact time. Meter parts should not be overly exposed. The solution can be brushed on thoroughly cleaned surfaces if soaking is not practical.

DISINFECTION OF OPERATING EQUIPMENT

PROBLEMS ENCOUNTERED

Disinfection of operating equipment is required when adverse tests indicate system contamination. Contamination by bacteria of intestinal origin may be indicated when tests indicate the

presence of coliform micro-organism. Taste and colour problems develop which may indicate the presence of iron bacteria and associated sulphur splitting bacteria.

A red water problem is caused by concentrated quantities of oxidized (ferric) iron. Sudden flow reversal or velocity change in the main will disturb settled iron which is then discharged to adjacent consumers. Minute quantities of iron, from the water source or the distribution system itself, can be concentrated by plain sedimentation of oxidized floc, or by iron bacteria. When iron bacteria are to blame a disinfection programme is called for. Also the absence of oxygen, especially in dead ends, will favour the reduction of sulphates to sulphides, which combine with iron and otherwise form odorous compounds. Where sulphides are formed a back sediment and offensive odours are very evident.

A red water problem may not be accompanied by an iron bacteria infestation. Hydrant flushings should be examined for Crenothrix and associated iron bacteria before disinfection is attempted. Disinfection will not remove iron from the system but will prevent deposition of iron by iron bacteria and the creation of iron sulphides.

DISINFECTION

The problems encountered in disinfecting an operating system are many, and varied. In general the aim is to apply a chlorine residual to infected equipment. The residual must

be low enough so as not to cause chlorine taste problems and high enough to reach the infected area. The residual must be held at the infected part long enough to allow complete disinfection.

Small Chlorinated Supplies

Where a water works system is equipped with chlorination facilities at the source, the distribution system or other appurtenances can be disinfected by increasing the chlorine residual leaving this source. The primary residual is raised to, say 0.5 ppm, and hydrant flushing is carried out to obtain some residual in the infected area. The disinfection programme can be carried out for a few weeks or as bacteriological results indicate. Flushing may have to be repeated a number of times to maintain a residual in the infected area. It is noted that even trace residuals over a long period of time will be effective.

In urgent cases, such as where serious coliform contamination is encountered, higher chlorine residuals may be warranted.

Large Chlorinated Supplies

In large distribution systems it may be difficult to maintain even a trace chlorine residual without having a very high residual at the source, and/or wasting excessive quantities of flushing water. The creation of a chloramine residual is sometimes a solution. The addition of one part ammonia to three parts chlorine will create this residual which will last longer

than a free chlorine residual. The disinfective power of this combined residual is greatly reduced over that of a free chlorine residual. Therefore, this change should not be made without careful consideration as to its effect on the bacteriological quality of the treated water.

When first attempting to blanket a large distribution system with a chlorine residual, taste problems may develop. Also, difficulty may be encountered in blanketing the system with even a chloramine residual. At first the oxidation and destruction of organic matter and various infestations will use up the applied higher residual, but after a time the taste problem should stop and the residual advance to the required areas. The end result will of course be a much cleaner distribution system.

Unchlorinated Supplies

When a water works system is not equipped with permanent chlorinator facilities, a temporary method must be devised to obtain the disinfecting residual in the infected parts. Batch addition of a chlorine solution or the installation of a chlorinator will be required. Generally the batch addition of chlorine solution is not to be recommended. Where a storage well is available, such as a spring reservoir, a simple drip arrangement may be devised for obtaining the necessary residual. Again the chlorine residual may be maintained at say 0.5 ppm at the nearest consumer. Frequent flushing may again be needed to maintain the required residual in the infected area.

The disinfection of a distribution system serving an unchlorinated well supply may require the installation of hypochlorinator or gas chlorinator on a temporary or permanent basis.

GENERAL

Notwithstanding the above, it is noted that every disinfection project is different and therefore it is impossible to cover every eventuality that may be encountered. In difficult instances, the interested regulatory body can be consulted for guidance.

REFERENCES

1. OWRC Senior Water Works Operators Course No. 1, Disinfection of Mains.

2. Manual for Water Plant Operators, A.A. Hirsch Chemical Publishing Company Inc., 212 Fifth Ave., N.Y. 10, N.Y.

3. Enviromental Sanitations, Joseph A. Salvato, John Wiley & Sons.

WATER TREATMENT PLANT - LABORATORY PROCEDURES

by

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An Address To
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WATER TREATMENT PLANT - LABORATORY PROCEDURES

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In conducting laboratory tests in a water treatment plant there are general precautions that should be observed. Water samples should be representative of the whole volume passing the sampling point at the time of collection. Samples that are turbid should be collected throughout the cross section of the stream or basin. If collecting well water for dissolved gas analyses, the sample should be taken from the well with a minimum of aeration and not at the discharge end of the delivery pipe. Certain tests such as for carbon dioxide, dissolved oxygen, dissolved iron, pH, residual chlorine and phenolphthalein alkalinity should be run immediately after collection of samples.

If a sample is turbid and a color test is to be run, the sample should be cleared. Filtration or centrifuging are used depending on the test to be run. For tests involving the production of a color, filtering the sample through a porous cylinder of diatomaceous earth called a Berkefeld filter candle is probably the best method. For pH and phenolphthalein alkalinity only centrifuging should be used since filtration alters the results.

Laboratory glassware should be kept clean and washed and rinsed after use. A closed cupboard is important for storing laboratory glassware especially in plants where the dust from chemicals being dosed may be floating in the air.

If it is necessary to weigh out chemicals for standard solutions used in titrations or color standards, a good analytical balance that will weigh to the fraction of a gram required should be used.

In many tests, various pieces of laboratory glassware are used. The buret, and pipette are the most common pieces used for measuring out standard solutions or indicators. The buret is graduated and the pipettes may be, so that a known amount of solution has been added to the sample under test. The graduate is a large cylinder used mainly for measuring out samples. This equipment should be read at eye level and the reading should be taken at the bottom of the concave shadow, or meniscus in the tube.

CHLORINE RESIDUALS

Since obtaining and preserving for a certain time a chlorine residual in the water being treated is a very important function in a water works plant using a surface water as the source of supply, the test of this chlorine residual is very important.

Chlorine in water may be present as free available chlorine, or as combined available chlorine both of which may be present simultaneously.

Some oxidizing agents, including free halogens such as bromine, iodine, other than chlorine will appear quantitatively as free chlorine; chlorine dioxide will also.

There are various methods in use and their use depends on the different conditions that are prevailing in the water sample. These methods are:

to be analyzed for chlorine cannot be stored, therefore, analysis should be started immediately after sampling.

For this basic course, since it is the most common method in use, only the ORTHOTOLIDINE METHOD will be discussed. This method measures both free and combined available chlorine.

There are a number of conditions that must be met so that the results will be accurate for this method: (1) The solution must be at pH 1.3 or lower during the contact period; (2) the ratio by weight of orthotolidine to chlorine must be at least 3:1; and (3) the chlorine concentration must not exceed 10 mg/l (ppm).

In purchasing the orthotolidine reagent it is better to specify orthotolidine dihydrochloride rather than the orthotolidine base. The dihydrochloride is considerably purer and dissolves in water readily which mades the test reagent easier to prepare.

The acid concentration in the reagent must be such that the pH of 1.3 or lower will be produced even with a sample of over 1,000 mg/l of alkalinity.

In conducting the test, the orthotolidine reagent must first be placed in the container being used for comparison and the sample added to it. This insures that the color development will take place at the pH 1.3 or lower and also that the ratio of orthotolidine to chlorine is at least 3:1.

Iodometric - This method is employed as a standard. It is also suitable for determining high chlorine residuals and is more precise than the orthotolidine method when the residual chlorine concentration is greater than 1 mg/l.

Orthotolidine - This method is widely used for routine measurement of residual chlorine in plant control and in the field.

Orthtolidine Flash Method - Is a qualitative method for free available chlorine.

Orthotolidine-Arsenite Method - This differentiates between free available chlorine, combined available chlorine and color due to interfering substances.

Drop Dilution Method - This is used for field use but is not accurate.

Amperometric Titration Method - Appears to be one of the most accurate available for the determination of free or combined available chlorine.

In all these tests it must be remembered that chlorine in aqueous solution is not stable and the chlorine content in samples or solutions will decrease; especially so in weak solutions. The reduction of the chlorine present will be accelerated by exposure to sunlight, strong light or agitation. Samples

Fresh orthotolidine reagent should be prepared after 6 months since occasional exposure to direct sunlight, or high or low temperatures may cause discolouration or precipitation and thus affect the readings obtained. Rubber stoppers should not be used on containers for orthotolidine since a reaction may occur between the rubber and the reagent.

The reaction time and temperature were chosen in this method so that the maximum proportion of the combined available chlorine would be measured while minimizing loss of color by fading or increase of color due to interfering oxidizing agents such as nitrite, ferric iron and certain compounds formed by chlorine with organic matter.

Various substances cause interference with the orthotolidine chlorine test and increase the apparent residual chlorine content of the sample. These interfering substances are nitrite, ferric compounds, manganic compounds, and possibly, algae.

If interfering substances are present the orthotolidine-arsenite method should be used.

APPARATUS

All readings should be taken by looking through the samples against an illuminated white surface. The surface may be opaque and illuminated by reflection or may be an opal diffusing glass illuminated from behind. Since chlorine determinations are made both day and night in water works control, it is preferable that

all comparisons be made with a standard artificial light. Two light sources are mentioned in the 11th edition of Standard Methods for Examination of Water and Waste-waters. If artificial light is not provided, "north" daylight should be used for comparisons. Comparisons should never be made in sunlight.

The equipment used to measure the color developed using ortho-tolidine varies a great deal in this province. The different kinds are: 100 ml Nessler tubes or bottles in which the color is compared visually with standards without any other equipment; Nessler tubes in a color comparator using a disk from which the chlorine concentrations are read directly; unknown and standards in a comparator where the two solutions being compared are side by side; color developed and colored solution is inserted into machine that measures light transmittance on a dial. The reading obtained is then transferred to a graph for chlorine concentration.

Except for the method using the disk, good color standards are necessary. According to Standard Methods the preparation of these permanent color standards is precise and instructions as it is stated there are explicit. Other texts use different simpler methods of making up the permanent standard solutions. The following procedure is given in Standard Methods for permanent chlorine standards.

PHOSPHATE BUFFER STOCK SOLUTION, 0.5M

Dry anhydrous disodium hydrogen orthophosphate Na_2HPO_4 overnight at 110°C and store in a dessicator. Dissolve 22.86g Na_2HPO_4 together with 46.16g anhydrous potassium dihydrogen orthophosphate KH_2PO_4 in distilled water and dilute to 1 litre. Let the solution

stand for several days to allow time for any precipitate to form. Filter out this precipitate before using.

PHOSPHATE BUFFER SOLUTION, 0.1M

This is a standard buffer, pH 6.45. Filter the stock solution as prepared above and dilute 200 ml to 1 liter with distilled water.

STRONG CHROMATE - DICHROMATE SOLUTION

Dissolve 155g potassium dichromate $K_2Cr_2O_7$ and 4.65g potassium chromate K_2CrO_4 in 0.1M phosphate buffer and dilute to 1 liter with 0.1M phosphate buffer. This solution corresponds to the color produced by 10 mg/1 chlorine in the standard orthotolidine procedure when viewed through a depth of 24 - 30 cm.

DILUTE CHROMATE-DICHROMATE SOLUTION:

Dissolve 0.155g potassium dichromate and 0.465g potassium chromate in 0.1M phosphate buffer and dilute to 1 liter with 0.1M phosphate buffer. This solution corresponds to the color produced by 1 mg/1 chlorine in the standard orthotolidine procedure when viewed through all cell depths.

MODIFIED SCOTT PERMANENT CHLORINE STANDARDS, 0.01-1.0 mg/1

The volumes of dilute chromate-dichromate solution indicated in Table I for the range of cell depths given are pipetted into 100-ml tubes of any uniform length and diameter or into 100-ml Volumetric flasks. The volume is then made up to the 100-ml mark with 0.1M phosphate buffer solution. These standards can be read at any cell depth up to 30 cm.

TABLE I CHLORINE STANDARDS

MODIFIED SCOTT FORMULA 0.01-1.0 MG/L

Chlorine mg/l	Chromate Dichromate Solution ml	Chlorine mg/l	Chromate Dichromate Solution ml
0.01	1	0.35	35
0.02	2	0.40	40
0.05	5	0.45	45
0.07	7	0.50	50
0.10	10	0.60	60
0.15	15	0.70	70
0.20	20	0.80	80
0.25	25	0.90	90
0.30	30	1.00	100

In using these standards and samples the color comparison tubes, cells, or bottles used in this determination should not differ in depth by more than 3 per cent. It is suggested that the top of the tubes be sealed with microcover glasses to protect them from dust and prevent evaporation.

ORTHOTOLIDINE REAGENT

This reagent is prepared by dissolving 1.35g orthotolidine dihydrochloride in 500 ml distilled water. Add this solution with constant stirring to a mixture of 350 ml distilled water and 150 ml conc. HCl.

This solution should be (1) stored in an amber bottle or in the dark; (11) protected from direct sunlight; (111) used no longer than 6 months; (1V) kept from contact with rubber; and, (V) maintained at normal temperatures. If the ortho-tolidine precipitates it cannot be redissolved easily and

errors can be caused by the use of solutions with a deficiency of orthotolidine caused by this precipitation.

SAMPLE COLLECTION

The sample should be collected from a point in the treatment plant that allows 15 minutes contact time from time of chlorine addition to sampling.

PROCEDURE

Use 0.5 ml of reagent for a 10-ml cell, 0.75 ml for a 15-ml cell and 5 ml for a 100-ml cell. The same ratio is used for other volumes. Place the orthotolidine reagent in the comparison tube, add sample to the proper volume and mix.

If the sample temperature is less than 20^{o}C (68^{o}F) it should be raised to that level quickly after mixing the sample with orthotolidine. This can be achieved by warming with hot water.

The color comparison should be made at the time of maximum color development. If the sample contains predominately free chlorine the maximum color appears almost instantly and begins to fade. If combined chlorine is present the color develops usually at a rate that is dependent upon temperature. The usual approximate times are 25^{o}C - 2.5 min., 20^{o}C - 3.0 min. and 0^{o}C - 6 min. About 5 min. after maximum color develops, a slight fading begins. Therefore, samples containing combined chlorine should be read before fading commences and the color should be allowed to develop in the dark.

If there is a natural color or turbidity in the sample, this can be compensated for by placing an untreated sample of the same thickness behind the standard and clean water behind the sample with orthotolidine in it.

If a colorimeter or photometer is used the sample will have to be measured and then decolorized and the remaining color reading subtracted from the apparent chlorine reading to give the true chlorine residual.

TURBIDITY

Turbidity in water is caused by the presence of suspended matter such as clay, silt, inorganic precipitates, finely divided organic matter, plankton and other microscopic organisms. Turbidity causes light to be scattered and absorbed rather than transmitted in straight lines through the sample. There is little direct relationship between the suspended solids concentration and the turbidity in a sample.

The standard method for the determination of turbidity is the JACKSON CANDLE METHOD. In this method the measurements are based on the depth of a suspension in a sample that just causes the image of a candle to become indistinguishable against the general background illumination when the flame is viewed through the suspension.

The instrument used is the JACKSON CANDLE TURBIDIMETER which consists of a standard candle supported at a definite distance below a graduated viewing tube. Certain precautions must be observed, such as trimming the wick of the candle, keeping

the bottom of the tube clean of soot, eliminating all drafts and keeping the tube free from scratches.

PROCEDURE

- for turbidities between 25 and 1000 units

The turbidimeter should be set up as described by the manufacturer. The sample should be well shaken and then approximately an inch of sample added to the tube. The candle should then be lit and the sample poured into the glass tube until the image of the candle flame just disappears from view. At this point, the bottom of the tube should appear uniformly illuminated with no bright spots. Near the end of the test it is convenient to add the sample from a pipette. This allows greater control and avoids rippling of the surface of the sample in the tube.

- for turbidities over 1000 units

In this case, the sample must be diluted below 1000 units with turbidity-free water. Each addition of dilution water should be of the same volume as the original sample. When the turbidity is below 1000 units - determined by checking after each addition of dilution water - the reading should be taken as in the case from 25 to 1000 units and multiplied by the factor:

$$\frac{\text{total volume of dilution water} + \text{volume of original sample}}{\text{original sample volume}}.$$

The Jackson candle turbidimeter has a lower limit of 25 units. For turbidities below that a Hellige turbidimeter that has been standardized with a Jackson candle turbidimeter can be used.

HELLIGE TURBIDIMETER

This instrument uses a standardized electric lamp as a source of light. Various sizes of glass containers are marked at various depths for samples of different turbidities. These different sizes used in combination with a cover glass/plunger determine the length of the light path through the sample. An adjustable optical system allows increasing amounts of light to enter the sample from the bottom to balance the light entering from behind the sample. Graphs are supplied so that the final adjustment in the amount of bottom light admitted as read on a dial can be converted to turbidity.

PROCEDURE

The sample is shaken well and poured into a container to the mark. The cover glass/plunger is placed on the container which is then set on the mirror instrument. The outside bottom of the container should be wiped dry so there will not be a film of water to cause errors.

The electric lamp is then switched on and with the dial set at zero and the door closed there should be a round dot visible at the bottom of the glass container when viewed through the eye piece. By rotating the dial the round dot should eventually merge with the rest of the bottom. The reading of the dial at this point should be transferred to the graphs to obtain the turbidity.

The dial should always be rotated in one direction until the end point is reached. If end point is doubtful the dial pointer should be returned to zero and the rotation repeated until checks are obtained. If material settles out on the bottom of the container the sample should be slowly stirred with a rubber-tipped stirrer and new readings taken.

In removing the sample from the instrument the container should be tilted slightly to avoid picking up the mirror. Moisture on the mirror may cause it to adhere to the bottom of the glass container and it may fall off and break.

The graphs supplied are specific for a definite electric lamp and/or size of sample container. Changing of either one necessitates the use of another graph. The graphs that are supplied list the lamp and size of container with which they are to be used.

JAR TESTS

The need for tests to determine how much coagulant and other chemicals must be added to remove color and turbidity is obvious. However, it is impractical to use a water treatment plant as the testing equipment especially when the pure water of a municipality may be endangered. For this reason, simulated tests using jars or other vessels were introduced. These first jar tests have been reported by some authors to have started around 1918. The early water works operators mixed their samples manually, either by shaking them or by using a hand stirrer. The first machines were used some years later and were somewhat crudely manufactured.

Jar tests can be used to investigate a number of treatments such as coagulation, softening, taste and odor control and iron removal.

A number of variables have an effect on the conduct of this test. The speed of revolution of the paddles, the duration of rapid and slow mixing, stirring of the sample should commence before the coagulant is added, the pH of the solution, the temperature of the sample, the size of sample, and the conditions existing at the water plant in question.

One of the essentials for this test is a stirring machine. One of the most common has six places for the jars and the stirrers are driven by a rheostat-controlled motor so that the speeds of the blades can be controlled over a wide range. Other pieces of equipment necessary are jars or beakers to hold the sample and pipettes with which to dose the samples. A laboratory timer and balance would also be useful. Some means must be provided of measuring the pH and temperature of the sample. In most plants it would be helpful if the same equipment was used each time a test is run so that the number of variables occurring be kept to a minimum.

Solutions must be made up for all of the different tests that will apply to the different types of treatment under consideration. Therefore, solutions or suspensions of coagulant, lime and activated carbon will be required.

The concentration of solutions can be adjusted to the preference of the person running the test. Generally they are made up so that 1 ml of solution or suspension added to 1 litre of the sample in the jar gives a dosage of 1 ppm. Therefore, if 1 litre of dosing solution is to be made up, one gram of material is used. Fractions or multiples of dosage, solution size or sample size necessitates adjustments in either dosing solution, concentration or volume added the sample. For example from the following table any combination can be calculated.

A	B	C	D	E
Dosage desired	Size of sample	Volume of dose	Volume of solution	Weight of material in D
	ml	ml	ml	gm
0.5 ppm*	500	1	500	0.125
0.5 ppm	1000	1	500	0.25
0.5 ppm	1000	1	1000	0.5
1.0 ppm	1000	1	1000	1.0
0.5 gpg+	500	1	500	1.78
0.5 gpg	1000	1	500	3.56
0.5 gpg	1000	1	1000	7.125
1.0 gpg	1000	1	1000	14.25

* ppm - parts per million, pounds per 100,000 Imp. gallons
\+ gpg - grains per gallon

PROCEDURE

The water works operator should set up a procedure that closely follows the treatment in the plant if at all possible. In this way, the best result obtained in the test should indicate the best result obtainable from the plant. This particularly applies to mixing times and rates. Once the most applicable procedure is found it should be followed every time the test

is run. In time, it may be possible to develop a factor between the test results and the plant results.

It is usually a little easier to set up a wide range of dosages first and determine within what dosages the desired treatment occurs. Then the range can be narrowed down and the final dosage determined.

For coagulation tests the sample should be at least one litre and the mixing should be started before the addition of the coagulant. Then the sample is stirred at a maximum rate for a few minutes. Following this the rate is decreased to very slow to condition the floc that has formed. The plant mixing time should not be exceeded at this slow rate but the test should continue up to that point as long as improvement is noted. Some authors suggest that the settling time be as long as the plant retention time but this may be impractical. This will have to be judged but turbidity readings can be used to determine whether further settling time is necessary.

In this test it is important that every sample in the jars or beakers be given the same treatment down to the smallest detail or the results may be misleading. Samples collected for turbidity after the test should all be collected at the same time. The collection of these samples should be done carefully to avoid getting the settled floc in the drawn-off sample.

Often activated carbon is to be used to remove tastes and odors and jar testing is used to determine the best dosage. In this case it is necessary to relate the contact period available in the plant to the mixing time in the jar test. To do this, the plant dosage is used in the jar test and the mixing rates are varied. The results of the odor test after the activated carbon jar test are compared with the odor from the plant itself. These results will indicate the mixing time which is used then for further tests.

All results obtained from the jar tests are then converted to dosages that would apply in the plant.

TASTE AND ODORS

Odors may be attributed to chemical materials produced by organic growths and to the presence of pollutants or other objectionable matter in the water. The distinction is not clear cut, as the introduction of a pollutant may greatly stimulate the growth of organisms that may produce objectionable tastes and odors. Incredibly small amounts of many odorous materials can cause tastes and odors. Experiments conducted by personnel at the Robert A. Taft Sanitary Engineering Centre at Cincinnati, Ohio, have frequently yielded a detectable odor from recovered materials in concentrations of two parts per billion and less. They say, in terms of quantities that are easier to visualize, that a single teaspoonful of pollutant can impart odor to 1 million gallons of water. Since these materials can be detected in such small quantities by taste and odor tests and are often

complex, it is usually impractical and often impossible to isolate and identify the causative chemical.

Taste and odor tests are very useful in a water plant to check quality of raw and finished water, to aid in setting-up jar tests for treating a taste and odor condition, and sometimes to identify the cause so that the source can be traced.

Taste tests and odor tests are quite similar except that the water must be safe to take into the mouth before a taste test. The odor test can be run at higher temperatures and thus an increased sensitivity obtained on some samples.

In conducting both these tests it is better to use panels of five to ten people or more to overcome the day to day sensory deficiencies of a single observer and to obtain a median of all the results.

These tests should be completed as soon as possible after the collection of the sample. If storage is necessary, a 500-ml, prechilled sample should be kept refrigerated in a thoroughly clean, glass-stoppered container.

The intensity of odor is expressed by a figure representing the number of times a sample has to be diluted with odor-free water so the odor can just be detected by the odor test. This figure is called the threshold odor number. This number will vary according to the temperature of the sample during the test. For hot threshold tests, 60°C (140°F) should be the standard temperature. Odors will be detected at this

temperature that might otherwise be missed and if these odors are not detectable in a cold sample, the test will indicate a developing odor condition. Certain industrial pollutants may volatilize at the 60°C temperature, and if it is thought that a lower result is being obtained by using that temperature, a cold threshold test should be run at 40°C (104°F). Taste tests should be run at 40°C since this is near body temperature and no hot or cold sensations will be experienced.

APPARATUS

The following apparatus is necessary to run a taste on odor test:

(a) Odor flask, 500-ml glass-stoppered Erlenmeyer with a fairly wide neck. One is needed for each dilution plus two for blanks.

(b) Thermometer, 0° - 110°C (32° - 230°F) chemical or metal-stem dial type. One is needed for each dilution.

(c) Graduated cylinders, capacity 10, 50, 100 and 200 ml.

(d) Pipettes, Mohr 10-ml graduated in tenths and 1 ml graduated in tenths.

(e) Glass-stoppered bottles, 500-ml to hold samples for testing.

(f) Erlenmeyer flasks, 2 litre, to hold odor-free water.

(g) Large hot plate or water bath. The hot plate should, for convenience sake, be checked for cold spots which can then be avoided when heating the samples.

(h) Odor-free water generator. This apparatus can be made out of a gallon jug. A glass tube should be bent in the shape of a sloping inverted L. The long arm of the L should reach

through the neck down into an inch of clean pea-sized gravel. The space between the gravel and the shoulder should be filled with 4 x 10-mesh granular activated carbon. Above the activated carbon a layer of glass wool is placed. Through the neck and into this layer of glass wool a second tube is placed. This tube is bent similar to the first one but with the leg inside the jug just reaching to the glass wool. The outside portion of this second or discharge tube should extend far enough beyond the side of the jug so that the storage container can be filled conveniently. Rubber or plastic tubing should not be connected to the discharge tube. The two tubes are inserted through a two-hole rubber stopper in the neck of the jug. If it can be fitted, the two-holed rubber stopper should be covered with aluminum or tin foil before it is inserted into the neck. This will help to decrease the surface area of the rubber exposed to the water.

ODOR-FREE WATER

This should be prepared as needed because it will absorb room odors. The tap water should be passed through the generator at the rate of approximately 1 litre per minute. Carbon fines will be washed out when the generator is first started; these fines should be discarded. Before the start of a test check the effluent from the generator for freedom from residual chlorine or odor. If not free, the carbon may need renewing.

PROCEDURE

The personnel in the panel conducting the test need not be extremely sensitive to odors but they must not be insensitive. Smoking and eating should be avoided just before the test. All strong odors and scents should also be avoided. The hands should be kept away from the neck of the flasks. If a panel is to be used for testing, it is better the samples be coded by someone other than a panel member. The temperature of the samples during testing should be kept within 1°C of the desired temperature for the test.

Before the threshold number test is made the taste and odor quality should be determined. Shake 200 ml of the sample at the desired temperature, sniff the odor lightly and record the description. For tasting, 10 - 15 ml of the sample at 40°C are placed in the mouth, held for several seconds and discharged. It need not be swallowed. Both aftertaste and taste in the mouth should be recorded. Do not taste any samples when its safety is in doubt.

In obtaining the threshold number the approximate range must be determined first. This is done by using the table below:

THRESHOLD ODOR NUMBER CORRESPONDING TO VARIOUS DILUTIONS

Sample volume diluted to 200 ml	Threshold odor number	Sample volume diluted to 200 ml	Threshold odor number
ml		ml	
200	1.	12	17
140	1.4	8.3	24
100	2	5.7	35
70	3	4	50
50	4	2.8	70
35	6	2	100
25	8	1.4	140
17	12	1.0	200

Add 200 ml, 50 ml, 12 ml, 2.8 ml of the sample to separate 500 ml, glass-stoppered Erlenmeyer flasks and dilute the contents to 200 ml with odor-free water. Another 200 ml of odor-free water is added to another flask to serve as reference. Heat samples and reference to the temperature decided for the test. The stoppers should be left slightly ajar to prevent any internal pressure from building up.

When the contents of the flasks have reached desired temperature, remove from the heat, shake the flask containing the odor-free water, remove the stopper and sniff the vapors. Then compare the odor in the flask containing the least amount of odor-bearing sample. If an odor is detected in this sample, further dilutions must be made. If no odor is detected, continue by smelling the next sample in the sequence until positive results are obtained. Once positive results are obtained a new set of dilutions must be made. The dilutions are made using the previous table. The dilutions range

from the dilution with the first positive result in the test just made to the next lower one dilution. For example, if the first positive result was obtained with the flask containing 50 ml of odor-bearing sample, the dilution range will be 50 ml, 35 ml, 25 ml, 17 ml, 12 ml.

Samples can be presented to the panel members in sequence, or presented at random, taking care that a strong sample is not smelled at the beginning. The panel or observers should not know which are samples and which are reference blanks.

The results are recorded by a plus sign if odor is detected and a minus sign if none is noted. Sometimes results are contradictory, a high dilution may be called positive and a lower dilution negative. When this happens the threshold is considered as the point where no further contradictions occur.

pH DETERMINATIONS

pH is defined as the logarithm of the reciprocal of the hydrogenion concentration in mols per litre. From the layman's point of view pH is a measure of the intensity of the alkalinity or acidity of a water sample. The practical pH scale ranges from 0, very acidic, to 14, very alkaline. The middle value of pH7 corresponds to exact neutrality at 25°C.

METHOD OF MEASURING pH

pH can be measured in various ways, the most common being electrometrically using a pH meter. Other methods are colorimetric using pH papers or pH indicators. The method using the

pH meter is considered the standard.

pH papers are difficult to read and are not reliable but the test is fast and convenient. The common litmus paper can be considered as a pH paper which just indicates whether a sample is acidic or alkaline. Some pH papers cover most of the pH range, while others may only cover a much narrower range of one pH unit.

To use the pH papers, the paper is dipped into the solution being tested. The paper will change in color, the amount of change being dependent upon the pH range of the paper and the pH of the sample. If the color change indicates the lowest or highest pH of the range of the paper, the next lower or higher range respectively of pH paper should be tried. This should be continued until the color change indicates the middle of a pH paper's range or if it is at the top or bottom of a range it remains there. The true pH colors are read at the tip of the paper being used.

Using colored solutions to measure pH does not need very expensive equipment but it has serious disadvantages. Color, turbidity, colloidal matter, free chlorine all affect colorimetric pH determinations. Both the pH indicators and the standards against which the samples are compared deteriorate. Sometimes, if a sample is poorly buffered, the pH indicator will alter the pH. It is suitable for a rough estimation.

The pH indicators are used by pipetting one millilitre of indicator into a portion of the sample. The color of the sample when compared with standards for that particular indicator, will indicate the pH of the sample. If a disk is used with a comparator the sample with the pH indicator in it is placed in the comparator and the disk revolved until a match is achieved.

In using a pH meter the manufacturers instructions should be followed in every detail. These instruments are usually quite fragile and should be treated with care. Batteries should be replaced when they are exhausted to prevent corrosion inside the meter.

BIBLIOGRAPHY

Standard Methods for the Examination of Water and Wastewaters, 11th Edition, 1960.

Journal of the American Water Works Association.

Manual for Water Plant Operators by A. S. Hirsch

INSTRUMENTATION & CONTROLS

by

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An Address To
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Basic Water Works Course
Toronto, Ontario
December 9, 1960

INSTRUMENTATION & CONTROLS

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INTRODUCTION

Since the days of the sundial man has constantly tried to improve his knowledge of science of measurement. The sundial itself was a major step forward in technological thinking but it suffered from the inherent weakness of being ineffective if the sun were hidden by clouds on a dull day. Today the improvements made on this instrument are such that at a predetermined hour a clock will waken us to the sound of a buzz or bell, and with an apparent understanding of human behaviour repeat its signal five or ten minutes later. The time measuring device can even go further by waking us to soft music, while simultaneously switching on the coffee percolator or pop-up toaster or both. This is a very interesting and desirable instrument but it obviously has limited use, as we wouldn't consider having such a clock strapped to our left wrist.

By this rather ridiculous analogy we can see that the very impressive advances made in the field of instrumentation have specialized uses and therefore limited application. The number and complexity of instruments and the degree of automation are almost always dependent on the size and capacity of our treatment works or pumping station.

We shall endeavour here to discuss some of the basic flow measuring devices and their application to the business of water treatment and supply. Instrumentation of water flow will be considered under these headings: - primary measuring devices, indicating and recording devices, and controlling devices operated from the primary instruments.

PRIMARY MEASURING DEVICES

Water flowing through a pipe suffers a pressure loss due to the decrease in static pressure being converted into velocity head. The principle of all flow measuring instruments is the measurement of the velocity head, expressed as $hv = \frac{v2}{2g}$ where hv is measured in feet of water, v is the velocity in feet per second and g is the acceleration due to gravity.

The most common instrument in use for flow measurement is the "Venturi" tube which consists of three sections. (1) An inlet convergent cone which increases the water velocity. (2) A throat section of diameter equal to the smallest diameter of the inlet cone. (3) An exit divergent cone which decreases the water velocity back to its original. The difference in pressure recorded between the entrance to the inlet cone and the throat section is a measure of the increase in velocity head which is interpreted in terms of the water flow. This interpretation is based on the "Continuity Equation" which states that for any pipe of varying diameter the product of cross-sectioned area and fluid velocity is constant or in

other words, considering two sections of a variable pipe (1) & (2): -

$A V = A_2 V_2$ where A = area and V = velocity. This product of area and velocity is known as Q and is called the "flow" or "rate of flow".

The Venturi tube has been in common use for a long time, is reliable over wide ranges of flow, and does not change in accuracy over extended periods of use.

ORIFICES

Orifices in thin plates are in common use for the measurement of flow, but due to their poor recovery of pressure head they are uneconomical for large flows. Their continued accuracy depends on maintaining sharp edges on the orifice. Orifices are the simplest differential pressure procedures and are cheap light and compact.

PITOT TUBE

Pitot Tube has wide use for flow measurements in mains where it is only necessary to insert the tube through a small hole in the main. The method of flow measurement uses two tubes, one of which has a right angled bend, which when inserted into the main, has the open end of the bent section facing upstream. This procedure permits the measurement of the total dynamic head which is the velocity head plus the static pressure head. The second tube has no bent section and is simply inserted into the main. This tube measures only the static pressure head. With both tubes graduated it is a simple matter to subtract the reading of the

second tube from that of the first to give the velocity head $hv = \frac{v^2}{2g}$. It is then simple to calculate the velocity $v = \sqrt{2ghv}$ and subsequently the rate of flow $Q = Av$ by calculating the internal cross sectional area of the main. This instrument is sensitive to turbulence which exists except at very low velocities but if there is a length of main equal to 50 diameters upstream from the Pitot then the average velocity is 0.83 to 0.85 times the measured velocity.

ROTAMETERS

Rotameters are mentioned because of their use in chemical feed equipment. A precision tapered glass tube contains a float whose position in the tube depends on a balance established between its weight and the effects of the upward flow of water. The float rises providing a greater opening for the chemical as the water flow rate increases.

CURRENT METERS

Current meters consist of a propellor connected to a revolution counter and are used extensively both for closed and open channel flow.

In most water works today there is little use of open channel flow since we take our water either directly from wells via pipes to our pumps or through an intake pipe from a lake to our treatment plant. Nevertheless it is worthwhile to note two important methods of measurement for open channel flow.

THE PARSHALL FLUME

The parshall flume is very similar to the venturi tube of closed pipe flow except that it is open and its bottom and sides are flat surface rather than conical.

WEIRS

Weirs of various forms employing many shapes of notches have been in use for a long time. The most popular appears to be the V-notch weir. The reliability and discharge properties are well established. They maintain good accuracy and are comparatively inexpensive. It is necessary to provide a stilling pool upstream from the weir to decrease the velocity of the water and so remove the turbulence of flow which prevents accurate measurement by weirs.

INDICATING AND RECORDING DEVICES

Once we have the instrument or mechanism that measures the flow, it is then necessary to transmit a reporting signal which usually takes the form of a difference in water pressure. A conversion mechanism is required to transmit the signal to a convenient location and which can actuate an indicator or recorder. Water columns containing floats connected by cables to differential gearing can be arranged to move a single output cable proportionally to flow.

Pneumatic transmitters convert input differential pressures into a single output air pressure which can be transmitted easily over considerable distances and used to activate indicating, recording and controlling devices. Electric instrumentation in which the differential pressure is converted into a suitable electric signal has similar versatility.

CONTROL OF RATES

Signals from pressure differential devices can be used to control water flows and maintain constant flows. Constant output rates are highly desirable for efficient performance in filter operation. The filters are protected from the results of the application of excessive wash water rates by the automatic control of filter washing rates, and so the standardization of washing procedures may be obtained.

Self acting controllers in which power obtained from the measuring device acts on diaphrams or pistons to operate control valves, have been standard equipment for a long time. They are compact, self contained, simple and reliable.

APPLICATIONS

We shall now deal with some of the instruments, mechanisms and controls found in the operation of a water works system. Some of the applications to be described are today only semi-automatic, in the sense that they are automatic in themselves but isolated from the rest of the plant. The operator under

such conditions may initiate the action after having received prior warning from his own senses or training, but he usually relies on warning from some instrument.

All of the applications which are described in detail are capable of being integrated into a completely automated system. The degree to which a water works plant is automated is dependent on a great variety of conditions, and each particular plant must be investigated in the light of these varying influences.

WATER SOURCES

When a source of water is an impounded reservoir, lake, river or well field, the level of the supply (hence its volume) is very important to the water works engineer, particularly if the available supply may be depleted in periods of drought.

When the level in a well drops, the surrounding ground water is being depleted and the amount of water being pumped may have to be limited unless the ground water is replenished. The ground water level in wells can be measured and recorded using float level systems.

Water levels at all these sources may be measured and the level indicated and recorded locally at the source and/or by means of telemetering at the pumping station or treatment plant.

RAW WATER INFLUENT

It is desirable to know the amount of water which flows (or is pumped) from the source of supply, in order to compare this quantity with the amount treated or pumped to the distribution system. This information discloses whether or not the carrying capacity of the transmission line is decreasing due to friction loss caused by either tuberculation or slime growths.

In water treatment plants, Venturi tubes and flow tubes are preferred as primary metering devices for flow measurement service in main lines because of their high accuracy and low head loss; to a lesser degree propeller type meters, magnetic flow meters, open channel flumes or weirs are also used for this service. The choice of an element is primarily based on permissible loss of head, first costs and piping requirements.

Venturi tubes and flow tubes create the lowest permanent head losses; while orifice plates are lowest in cost. All of these primary elements restrict the cross-sectional area of the flow so that the flow rate is dependent on one measurable variable -- the head loss across the element.

COAGULATION

As is well known, chemical coagulation takes place at an optimum pH value. The controller operates the lime feeder in such a manner as to provide a final pH of optimum value for

coagulation; a valve controls the addition of a solution or adjusts the speed of operation of the chemical feeder through the use of a d-c motor operating from a rectified a-c source. If the character of the water changes over a period of time and it is found that there is another optimum pH control point, it is necessary merely to adjust the index setting of the pH controller.

The dosage of coagulant is generally in proportion to the rate of flow -- that is, so many grains per gallon or parts per million.

If a pneumatic controller were used, the alum feeder would be equipped either with a pneumatic rheostat and d-c motor or with a pneumatic operator for changing the feed rate. The control of those two variables in the chemical coagulation process would eliminate the necessity for frequent checking of the dosage rate of coagulant and the pH of the water in the coagulation basin.

FILTRATION

Instrumentation and mechanical control of rapid sand filters has been used in water works plants for many years. The use of mechanisms became necessary because of the complex sequence of events in backwashing a filter. It was found that the sequence could be performed much better mechanically than manually. Today, it is possible to specify rapid sand filters which do not even require the full time attention of an operator. Today automatic control systems make it possible to completely supervise and operate water treatment plants from the laboratory or

superintendent's office. Operating tables at each filter are no longer essential.

Control systems may be as simple or as automatic as you want them. Whether a filter is controlled manually or automatically -- from operating tables or central panel boards, efficient control is based on the accurate measurement of effluent flow rate, filter loss of head, sand expansion, wash water flow rate, wash water level and clearwell level.

Very few filtration plants have simple manual control because with very little additional investment, it is possible to include automatic control of effluent and filter backwash rates of flow.

Actual washing requires about 5 minutes, although the bed is out of operation for 10 to 15 minutes. The steps in washing are as follows:

1. Close the influent valve. The filter is allowed to operate until the water level reaches the edges of the troughs, although some operators permit it to fall to about 6 in. from the sand.

2. Close the effluent valve.

3. Open waste water valve to sewer.

4. Open wash water valve. It is advisable to turn on the wash water gradually to prevent dislodgement of the finer gravel. The full washing rate should not be applied until water is passing through the sand. Washing continues until the wash water appears fairly clear to the operator.

5. Close wash water valve.

6. Close waste water valve to the sewer.

7. Open influent valve.

8. Open effluent valve.

Most filters have a rewash, or filtered-waste valve which permits wasting of filtered water to the sewer. If considered necessary, the eighth step above would be opening the rewash valve and wasting water for 2 to 4 minutes. The valve would then be closed, and the effluent opened.

THE CONTROL SYSTEM

The usual loss-of-head gauge consists of a vessel of mercury connected by one pipe to the water above the sand and by another to the effluent pipe so that the differential between the two heads will be indicated by the mercury level. Mechanical operation of these gauges by cables or chains, formerly universal, is now largely confined to smaller and older plants. Most large plants today use pneumatically actuated gauges, whose actuators can be located as desired, and whose small copper tubing connections do not obstruct the pipe gallery.

Rate of filtration is measured by means of a venturi meter in the effluent line. Summation of the flow through the filter and of several flow meter readings in the filter plant is frequently desirable, for automatic control of chemical feeders in proportion

to the total flow through several main lines. The summated flow may be shown on a single recording instrument in the superintendent's office or on a large dial illuminated indicator in the filter plant or both.

One highly important device is the filtration rate controller which maintains the filtration rate at some predetermined figure. Immediately after a bed is washed, water would pass through the sand at a high velocity and with insufficient treatment. Accordingly the effluent line must be throttled down to keep the flow at the proper rate. As clogging occurs, the throttling must be reduced to prevent a slowing down, thus to keep the rate constant and also prevent injurious brief fluctuations. It is not satisfactory to attempt this manually, and automatic devices have been developed, most of them depending on the venturi meter principle.

Rate-of-flow controllers developed for use in filtration are of two basic types, the self-powered and the servo-powered. Both types utilize the differential pressure created by flow through a Venturi tube as the source of regulation.

Master controllers are used in very large plants. They are designed to fit special needs and may automatically slow down filters when the clear well becomes full, and vice versa, or may be of a type that permits all or some of the filters to be adjusted in rate at a central point. A constant depth of water over the filters while in operations is maintained in some older plants by a hand-operated valve placed in the line

supplying water to the mixing and coagulation basins. In other plants the supply valve is automatically operated by a float valve actuated by the water level over the filters or in the sedimentation basin.

A wash water rate controller is very desirable in a filtration plant. The controller regulates the backwash rates to protect the filter bed from an accidental excessive flow. A meter showing wash water volumes used should also be provided in every plant in order to determine the net water gained in the treatment.

FULLY AUTOMATIC CONTROL

Automatic control systems go even further in controlling backwashing and rewashing sequence with the valves being activated automatically in accordance with the loss of head. When this control feature is included, the operator establishes the loss of head at which backwashing is to begin, and then automatic sequencing switches are actuated when the loss of head across the particular filter reaches that point. Special hold-outs are included so that only one filter is backwashed at a time, and only one sequencing circuit is required for each plant.

CHEMICAL FEED CONTROL

Chemical feeders are divided into three types. Solids feeders, liquid feeders and gas feeders. Solids feeders may feed either on a volumetric basis or on a gravimetric basis. Gravimetric feeders may be either loss-in-weight or belt gravimetric types; liquid feeders may be volumetric feeders including decant

types, or positive displacement feeders including the Archimedes wheel (Roto dip) or loss-in-weight feeders, and the proportioning pump, either diaphragm or piston. Gas chemical feeders usually operate on the basis of volume measurement through an orifice under controlled conditions.

TYPES AND MODES OF CONTROL

The types of control are mechanical, electrical, electronic, and pneumatic. The modes of control are two position (on-off), proportional; proportional-plus-reset, and floating (single-speed and proportional-speed). There is very little choice among the types of control as far as acceptability and utility are concerned. Each has its proper place, and each may be complex or simple depending on the requirements of the application. The type names in themselves are in the most part self-explanatory, so there is little need of an extended discussion.

CHLORINATION

In general, approved chlorine feeders operate by injector induced vacuum, measure the chlorine in the gaseous state, dissolve it in water and direct the solution to the main flow of water being treated. Chlorine gas feeders may be controlled manually at set rates of feed, semi-automatically paced in step with main line flow from Venturi, propeller type Telemeter or summation units. Supplementary instruments used in conjunction with chlorine feeders include those which measure

and record the concentration of chlorine in the treated water, those which record the rate of flow of chlorine passing through the chlorine feeder and loss in weight from storage cylinders on weighing scales.

Chlorine gas feeders incorporate automatic safety controls to assure protection of the operating personnel, and also incorporate flow control devices to govern with a high degree of accuracy the application of the chlorine to the water system.

DISTRIBUTION SYSTEM

The distribution system of a water works includes not only the transmission mains, services and elevated storage tanks, but also the pumps at the treatment plant or well pumping station and any booster pumping stations.

Pressure control is applied in water distribution systems to permit maintenance of the correct fire hydrant pressure as well as sufficient pressure to avoid dangers of back siphonage and to assure availability of water for all commercial and domestic uses.

A simple example of pressure control is the automatic operation of well or high lift pumps to meet varying demands on a water system. This can be done by level sensing, or pressure sensing devices installed at strategic locations in the system such as the high point where minimum pressure would be expected. The pressure is transmitted by signal to a centrally located receiver to operate an indicator-recorder. The cycle is then completed by

incorporating a transmitter in the control panel which signals a receiver and actuator at the pump station to start or stop one or more pumps as the pressure decreases or increases. To some extent the same control system can be applied to position butterfly valves in gravity flow situations or for pump throttling. Pressure sensing devices can be placed on both the suction and discharge side of the booster pumps, with transmission to indicator-recorders at the control center, thereby providing information on available storage, line pressure and number of pumps operating. This would permit the control center operator to observe the situation at the booster station at a glance and would allow him to over-ride the automatic operation if desired. Pressure control can involve telemetering a signal automatically to a starter motor for a standby diesel engine in the event of pump failure or the need of the additional pumping capacity of the diesel-driven unit. Other examples of pressure control are positioning a butterfly valve to avoid back pressure from stopping a pump and operating pilot controls on valves for pressure reduction.

DISTRIBUTION SYSTEM CONTROL

From a control standpoint all distribution systems break into two broad classifications, primary systems and secondary or booster systems. The former refers to the system taking water from some natural source and delivering it to treatment, storage or use, or a combination thereof. The secondary or

booster system is a localized improvement of a primary condition to increase pressure or flow, but with the source of water from a primary system.

In a primary system the problem is to deliver an adequate flow of water at reasonable pressure from every tap in every section of the system at all times. To accomplish this there are two main systems, the elevated tank system and the direct pumping or tankless system.

ELEVATED TANK SYSTEMS

The most common type of distribution system is the elevated tank system where the basic pumping unit is the single pump, untreated or raw water installation. On this simplest of systems the problem of automation is equally simple. The system is supplied by maintaining the tank. This is done automatically by literally weighing the tank through measuring the pressure in the system.

DIRECT PUMPING SYSTEM

The second primary division of a distribution system is the tankless or direct pumpage system. This is not a new method, having been used industrially for many years. It has also been used on many municipal installations but generally has been restricted to the larger systems. The tankless system, properly understood and properly controlled, actually is the most efficient and most stable water distribution system in existence. The pressure holds within closer limits; it saves power; it is a tempered system.

The tankless system by definition is one with no storage reservoir or cushion tank for stability. Its total storage is the composite volume of the distribution piping. The tankless system like any other to be efficient must be properly designed and properly applied.

The tankless system uses the pump as a flowmeter and regulates the pumping to the flow requirements. Flow is measured by the pressure drop across an orifice. All pumps have a characteristic curve, one axis being head or pressure, and the other axis being flow. In a tankless system, through the pump, the pressure at any given moment has to reflect the flow at that moment. Just as with the flowmeter and its orifice, using the pump as our flowmeter, flow is being measured by pressure.

TANK LOCATION

With the previously available methods of automatic pump control, the location of elevated storage tanks has been dictated by the limitations of the control almost as much as by topography. Better service can always be obtained when the tank is located at a distance from the pump, as heavy demands can surely be better served from two directions than from one. However, because the pressure at the pump is so greatly increased by pipe friction when the tank is far from the pump, remote control must usually be provided if automatic operation is to be successfully used.

EQUIPMENT REQUIRED

The essential parts of the simplest, one-pump, control are: (1) a pressure switch to start the pump at the minimum desired discharge pressure, and (2) an electrical contact actuated by a water-flow meter in the pump discharge. This contact continues the pump in operation after the pressure switch has opened because of the increased pressure produced by the running pump. The Switch does not open again until the volume delivered by the pump falls below the desired minimum.

Although the control requires a meter to determine the flow, this is already almost a necessity in the modern pumping station, not only for the records obtained but also to provide a ready means of determining load fluctuations, total flow and pump efficiency. Of course, if more than one pump is used, only one meter is required for the pressure-flow control, provided that a common header with a single outlet may be used.

AUTOMATIC OPERATION OF SMALL WATER PLANTS

Most small well water plants consist of one or more wells pumping into a ground storage reservoir, plus 2 or more booster or high service pumps delivering from the ground storage tank into the distribution system. Automatic control can be utilized with this type of plant to assure operation of all equipment under near optimum conditions and to assure a water supply even with failure of individual components.

Since the water well is pumping into a reservoir, its pumping cycle can be based on the requirements of the well itself rather than directly on the demands of the distribution system. A ground storage reservoir usually has a capacity which is large in comparison with the pumping rate of the well so that a significant change in level in the reservoir will allow the well to pump for a reasonable period of time. Consequently, the well is controlled by the level in the storage tank. This level can be measured by a float, by immersion electrodes or by a sensitive pressure device. The pressure switch can be a pressure switch or pressure indicator with provision for actuation of a switch or switches. Floats and immersion electrodes are not generally as desirable as sensitive pressure elements due to the possibility of mechanical binding or jamming and freezing in cold weather. It is generally inadvisable to allow the level in the ground storage tank to drop below the half full point in order to have some water available in the event of well pump failure.

Another function of the ground storage level sensing device is to assure that the booster or high lift pumps will not run when the level is low enough to cause them to lose suction with consequent drainage to the pumps. When the level drops to the minimum safe suction pressure a switch is actuated which kills the circuit to the booster pumps and sets off an alarm, such as a horn. This alarm can be silenced by means of a push button but should be of the automatic resetting type that cannot be permanently silenced by the operator. When the reservoir has filled to a safe level, automatic operation is again resumed.

The high lift or booster pumps are controlled from distribution system pressure or elevated storage tank level. If elevated storage, or some other method for maintaining pressure in the distribution system, is not provided then at least one of the booster pumps must be in continuous operation. An elevated storage tank floating on the line is provided in most systems. Elevated tank level can be determined most commonly by means of a pressure sensing device tied into the system at the bottom of the elevated tank riser. If the elevated tank is close to the water plant itself, pressure switches or other pressure sensitive devices which can actuate switches are used for control of the booster pumps directly. If the elevated tank is a considerable distance from the water plant, telemetering equipment of some kind is necessary to relay this information back to the control system. This is usually done by utilization of leased telephone lines.

As a safeguard; and to facilitate startup and routine testing, all pumping unit controls should have 3-position selector switches for hand-off-automatic operation.

Adjustable time delay relays should be provided for the starting and stopping of all the pumping units. This precludes the possibility of surges causing the pump to start and to stop in rapid sequence. This is particularly undesirable in the case of the water well since frequent starting and stopping may cause the well to sand up.

CONCLUSIONS

As we can see from the preceding, the scientific advances made in the field of instrumentation have been quite explosive in recent times providing a great many types of measuring and controlling mechanisms for all possible operations in the water treatment and distribution field. There are still a great many problems attached to this field particularly in the decisions affecting the selection of more or less automation for any specific project.

There is no doubt that automation will become more and more important in the sanitary engineering field and we must be prepared for it. The problem in instrumentation and automation of water works is really being able to understand its capabilities and its short comings. We must not avoid automation because we do not fully understand it nor must we rush headlong into automation because its the coming thing.

Today as more operations become automated we must be ready to enter the "Age of Automation" with knowledge, intelligence and an open mind. We must be aware of both its advantages and disadvantages and be ready to accept it, if it will provide us with cheaper, more efficient and more reliable operation while maintaining safety for the public.

COLD WEATHER OPERATION

by

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An Address To
The Ontario Water Resources Commission
Basic Water Works Course
Toronto, Ontario
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COLD WEATHER OPERATION

D. Caverly

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It is hoped to present a brief descriptive treatment of the experiences, methods and operating procedures of a water system during freezing weather in an attempt to maintain the continuity of water services under adverse conditions. An analytical treatment of frost penetration, density, texture and thermal conductivity of soils, and other phenomena such as super cooling of water and formation of solid ice crystals is beyond the scope of this lecture.

PREVENTIVE PROCEDURES

It is possible to plan and construct a water system to such standards that there would be no operating problems due to freezing weather. Such a system would however involve tremendous expense in original cost and in routine operation and maintenance. In this respect, each designer or operator must determine what optimum standards or procedures to follow, consistent with the expected cold weather pattern in the area, and consider the economics of deviating from this norm. These procedures are usually determined by direct experience or the experience of other successful installations under similar conditions. The system should be constructed to standards that are sufficient to protect the facilities during normal freezes plus a reasonable factor of safety below this point.

UNDERGROUND FACILITIES

General depth standards have been developed, suitable for each area. In the Toronto area water mains are normally installed with a minimum of 5 1/2' - 6' cover and house services are usually given at least 4 1/2' of cover. The main reason is for frost protection but there are other factors involved in the depth location of a water main eg. soil conditions, existence of other underground utilities, etc.

EQUIPMENT AND TOOLS

Needless to say, all work and maintenance equipment should be checked, serviced and winterized prior to the freezing season. Mobile and power equipment should be available for duty under all conditions. During extremely cold weather, it is wise to store air compressors, portable pumps, generators and other power driven equipment in a heated or otherwise protected enclosure. This ensures quick starting of motors and the availability of equipment when required.

Power and air tools should be in good working order and small hand tools and special items such as turn off or curb cock keys, wrenches etc. should be on hand in sufficient quantities to supply additional emergency crews. Extra street baricades, red lanterns or other warning devices, should be available.

MATERIALS AND SUPPLIES

Sufficient quantities of spare and repair parts should be available, including pipe, pipe repair clamps, sleeves and couplings, water service parts, meter repair parts etc.

When ice forms on the street surface after the escape of water from a broken main or service, a supply of sand should be available to be scattered on the ice.

MAIN BREAKS

Extremely cold weather usually results in a higher frequency of broken or ruptured mains. This is caused by the additional stresses induced in the pipe by rapid fluctuations in the temperature of the water. The medium surrounding the pipe is gravel backfill clay sand etc. becomes progressively colder and the water travelling in the main may change in temperature quite rapidly. Stresses which are caused by lengthwise contractions of the pipe are cumulative and add to the existing stresses due to internal pressure and cause tension breaks which are characterized by being circumferential or perpendicular to the axis of the pipe. There is a slight loss of strength because pipe materials become more brittle at lower temperatures. The converse is true when there is an abrupt rise in temperature; the breaks then caused are the result of extreme compression at the point of rupture, caused by cumulative expansion of the pipe. It is therefore evident that complete protection of the pipe from external freezing conditions will not eliminate breaks if the water flows through the pipes too rapidly and is subject to severe temperature changes.

REPAIRS TO MAINS

Repairs to broken mains must be given top priority and crews conducting this work should be supplemented when required. During emergency periods trained personnel should be concentrated on the repair of the break and minor repairs or routine duties should be assigned to others where possible.

Freezing of non-circulating mains subject to exposure can often be prevented by opening the blow-off connection at the dead end and permitting a constant flow of water during severe weather. This should be adopted as a normal operating procedure on mains suspended from bridges and culverts where adequate protection is not provided.

Where mains do freeze as a result of say shallow depth of installation, one method of thawing that has been tried is the application of an electrical current and utilizing the heat created by the electrical resistance of the pipe to thaw the main. Varying degrees of success have been achieved but there are a number of important disadvantages. The amount of current necessary to thaw sections of frozen pipe by resistance is relatively large and can be hazardous under certain conditions. The rubber rings in hydraulic couplings can be severly damaged. Iron rust and scale deposited on the inside of the pipe can be loosened in steel pipe by the action of electrolysis.

The best protection against freezing of mains and services is to install them at a reasonable depth below the normal line of frost penetration. It has been found, after a break occurs, that old mains had been installed at too shallow a depth or that street grading operations had subsequently removed some of the cover. As soon as such a condition is discovered the mains should be sheduled for lowering or replacement. Sometimes the discovery is not made until freezing has actually occured and then it is necessary to thaw and restore the frozen section under the worst possible working conditions. In such repairs, frozen fill or spoil should not be used for backfilling.

METERS AND SERVICES

Water meters are most susceptible to freezing being closer to the ground surface ie. when they are yard or curb meters located outside the house or building. In most localities, especially the Toronto area, all the new meter installations are made inside the building and are thus protected. Meters that are installed outside are normally set at a depth of 3 1/2' - 4' depending on climate conditions but these are not widely used.

HYDRANTS

Hydrants should be inspected at least once each year preferably prior to freezing weather. One of the most important checks to make is that the hydrant drains properly after closing. Where the general soil conditions are sand or sandy clay, it is generally very easy for

water to drain away from the hydrant through a small hole at the bottom of the barrel. However, in more clayey soils the greater impermeability prevents good drainage and it is therefore often necessary to pump the water out of the hydrant. Hydrants known to be used during the winter usually require additional inspections. Sometimes hydrants are mistakenly thought to be frozen in extremely cold weather because the operating stem sticks or seizes in the bonnet gland packing. This seizing of the stem may be caused by the small amount of moisture or condensation sometimes present around the gland. Firemen should be advised to expect this condition occasionally. A small ring of waste or packing saturated in kerosene, placed round the operating nut or bonnet shield and ignited will thaw out the gland immediately.

CUSTOMER SERVICE

Experience has shown that if temperature conditions run true to pattern, the greatest frequency of shut-off calls occurs during the two periods of 4:30 - 8:30 p.m. and 6:00 - 8:00 a.m. The afternoon rise in call frequency is probably because most people are at work during the day and discover the trouble upon their return. The early morning rise in call frequency is undoubtedly attributable to discovery of the trouble when the customers arise and to the fact that the extremely low temperatures encountered usually occur at about sunrise. Where possible, duty hours of personnel should be adjusted to meet these peaks.

PLANT PROBLEMS

Problems of freezing in the operation of pumping and filtration facilities are usually minor if the plant is properly designed and operated. It is not too difficult or expensive to eliminate most of the risks of freezing. On some cases there may be difficulty with anchored ice in exposed basins or tanks. Damage to baffles, weirs, or other facilities may result if the ice anchors to such appurtenances and if there is a subsequent change in the level supporting the ice. Either the ice must be kept broken up or the water level must be held nearly constant.

It is often advisable to apply heat to liquid chlorine cylinders and to gas chlorinators to maintain operating pressures. At lower temperatures, there is some loss of efficiency and reaction time of chemicals, especially alum and hence a greater amount of suspended matter may reach the filters.

RISERS, GAUGES AND INSTRUMENTS

There are always some devices or appurtenances that may be overlooked from the standpoint of freezing protection. Among these are recording or indicating pressure gauges on outdoor installation. If electric power is available at the installation, consideration should be given to the permanent installation of small resistance strip heaters in an enclosure with the gauge or measuring device. These heaters also serve to keep down moisture

around precision equipment. If electric power is not available at the location, provision should be made for one or more ordinary kerosene lanterns during extremely cold weather.

Many of the newer plants today have all or most of the gauges and measuring devices located inside one control building which obviates the necessity of individual protection of instruments.

Gauge lines or pilot lines may sometimes be exposed with no reasonable or economical way to protect them. There are several types of electric heating wire that can be wrapped around the exposed pipe.

Water level-indicating floats and float switch controls should not be located too near the wall of exposed tanks where ice may form. In small tanks it may be possible to use a probe to break away the ice on the surface of the water, if the ice interferes with the operation of floats.

Small diameter risers to elevated tanks should be jacketed and insulated. If the riser is 12" diameter or less there is a probability of solid freezing during prolonged periods of subfreezing weather.

CONCLUSIONS

Although it may not be possible to guarantee the protection of all facilities by the procedures described, it has been found

by experience that they have helped to minimize what might otherwise have proved to be crippling circumstances. These procedures have been developed over a period of years and have worked so efficiently that their continued use seems to be warranted. It should be emphasized that the most important factor in operating under emergency conditions, is the whole hearted cooperation of competent supervisors and personnel. It is to those people that full credit should be given for a job well done.

OPERATION IN EMERGENCIES

by

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An Address To
The Ontario Water Works Commission
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OPERATION IN EMERGENCIES

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INTRODUCTION

Emergencies which may be caused by flood, storm, fire and explosion are unpredictable. Every water works, whether operated by a municipality, public utilities commission, institution or private company, should have a plan to place into immediate action should disaster come. The water works should aim to maintain pressure in the distribution system, to make needed repairs promptly, to proceed with emergency chlorination until all danger from contamination is passed and to keep its consumers informed throughout all stages of the disaster.

A review of the material published in the American Water Works Association Journal shows that the topic of emergency operation has been discussed by three different interest groups in the water works field. Many of the articles written are for the benefit of management and cover such subjects as emergency organization planning, communications, press and public relations, personnel training, emergency headquarters location and provision of emergency supplies. Important planning considerations, such as the safe location of water works, alternate water supplies, standby and alternate power supplies and the location and type of control valves, are written by designers and builders of water works systems. Information is also available on the actual operation of the water works during periods of emergency.

Unfortunately, floods, hurricanes and electrical and ice storms are not unknown to Ontario. All plant operators should be familiar with the following emergency operating procedures and should be prepared to carry them out at short notice. Operation through difficulties arising from severe cold weather, obsolesence, improper design, inadequate maintenance, water hammer and war are not included.

CHLORINATION TREATMENT AT THE WATER WORKS

Flood waters entering the system from the water works should be chlorinated at such a rate as to give a chlorine residual of about 2 p.p.m. after 15 minutes contact time. Personnel with chlorine testing kits should begin to fan out from the plant to determine the travel of the chlorinated water. The rate of application should then be adjusted to maintain a chlorine residual of between 0.5 and 1.0 p.p.m. in all parts of the distribution system. Any spot that does not clear up within a reasonable period of time should be flushed by opening hydrants. Bacteriological samples should also be taken to prove the effectiveness of the chlorination.

An unpalatable water drives consumers to use other waters which may be unsafe. If heavy chlorination causes objectionable tastes and odours, ammonia in the form of ammonium sulphate or anhydrous ammonia may also be added at the water works to minimize tastes due to chlorine. Concentrations of chlorine in excess of

1 p.p.m. may kill goldfish. The consumer should be educated to consider the smell and taste of chlorine as a sign of safe water rather than undesirable water.

If the distribution system becomes contaminated during the disaster or following it, the health department officials through the disaster headquarters should issue a warning that all water used for drinking and cooking purposes should be boiled until the system has been found bacteriologically safe.

SHUT DOWN PROCEDURES

If it becomes necessary to shut down the water works, all consumers should be warned in advance. The people should be asked to store water but not to fill bathtubs in order to avoid a sudden demand on the system which may dangerously deplete pressures and reduce fire flows:

(1) Well Supplies

When a flood threatens to cover a well, the unit should be run continuously to fill all storage reservoirs. The motor shaft should then be uncoupled; the bolt holding the motor frame to the bedpipe loosened; and the motor blocked high enough in the air to be out of reach of the water. The breather pipe should be plugged. Every effort should be made to keep the flood water from entering and contaminating the well. A ring levy of clay mud and sand bags will hold back five feet of water if built wide enough.

(2) Surface Supplies

As flood waters reach the elevation at which the water plant's protection levies will be topped or a break may occur, the operator should begin to prepare the plant for shut down.

In all electric powered plants, the first step is the notification of the power company when the entire plant will be shut down. After emergency, portable standby lighting equipment has been put in service, all switches controlling incoming electric power should be opened and tests made after the power is turned off to make sure that no electric current will reach the plant after flooding begins. Other precautions, such as removing gasoline and oil stored below high water level, should be taken. These materials, spread over the water surface, create a fire hazard and make the cleaning of equipment difficult.

At steam powered plants the fires should be extinguished far enough in advance of the actual flooding of the boiler room to permit the firebox lining to cool. This will reduce the fractured damage to fire brick when it is suddenly subjected to cold water.

All readily removable items of equipment, chemicals and supplies should be secured out of danger.

(3) Distribution System

In order to cope with distribution system emergencies, special service vehicles should be available and equipped with two-way radios, hand or power operated valve keys, auxiliary generators for emergency lighting, pressure gauges, pipe and valve locaters and chlorination equipment.

Probably the most important item is a complete set of maps and notes showing reservoir lay-outs, feeder mains, distribution mains, stream crossings and control valves at street intersections.

The loss of bridges and wash-outs may necessitate the shut-down of larger feeder mains. The shutting down of a large main is not a casual operation but one calling for speed, training, and previously planned procedure. There must be some means of knowing when a break occurs and on what main. This information should be transmitted to the repair crews as soon as possible. The man in charge of the crew should have a plan showing what valves are to be operated to effect the desired results. It should be pointed out that it may take three to four men up to thirty minutes to close manually operated 12-inch or 16-inch gate valves.

A flooded distribution system should not be polluted if the pressure has not been off in the system.

DISINFECTION OF MAINS

The principle causes of contamination are:

1. Main breaks;
2. Back-flow through faulty plumbing;
3. Cross-connections;
4. Reduced pressure within the system.

There may be a tendency to overlook disinfection when the need for resoring services is grave. Regardless of the urgency, disinfection must be carried out. For the disinfection of contaminated mains the following procedure should be used:

1. Shut off main;
2. Repair main as soon as possible;
3. Thoroughly flush main of all sediment;
4. Inject 50 p.p.m. chlorine and rest for 4 to 24 hours;
5. Flush main thoroughly;
6. Enter premises and instruct the occupants to flush the system by opening every faucet for fifteen minutes.

It is important to thoroughly cleanse and flush the mains before treatment is commenced. Disinfection of grossly contaminated mains may be facilitated by first sludging the system with a heavy dose of 200 to 250 p.p.m. and following this by water containing 50 p.p.m. for 4 to 24 hours. The chlorine may be applied by means of mobile chlorinating units or by using

hypochlorite powder or solution. Some operators prefer to use portable chlorination equipment rather than relying on the placing of hypochlorite in each length of pipe. Other operators prefer to keep all chlorination equipment at the water works and provide for disinfection of mains with the least amount of equipment.

The system can also be disinfected by raising the pH to 10.5 with common hydrated lime. When flushing the system it is necessary to see that the pH is 10.5 at all ends of the system.

EMERGENCY CHLORINATION METHODS:

A complete description of a temporary chlorine cylinder filling station from tank cars is given in the September, 1954 issue of the AWWA Journal. The article written by Mr. B. L. Shera also describes how calcium hypochlorite solution can be made from lime and liquid chlorine.

The presence of chlorine is usually detected by means of orthotolidine. Chlorine residuals up to 10 p.p.m. will give a yellow colour with orthotolidine. Residuals between 15 to 20 p.p.m. give a bright red colour, and residuals of about 50 p.p.m. give a brown precipitate with orthotolidine.

1. Direct Gas Feeding

A dry feed gas chlorinator consists essentially of a reducing valve and a rate of flow indicator. Fluctuations

in gas pressure due to temperature variations of the liquid chlorine are minimized by enclosing the cylinder within a vertical nest of cells through which pass tap water.

If a dry feed gas chlorinator is used to apply chlorine to an open flume, the diffuser on the end of the supply line should be submerged at least four feet and preferrably six feet.

A chlorine cylinder without equipment may be used for direct feed during an emergency, controlling the rate by counting the bubbles per minute through a water trap. Low sensitivity of the cylinder valve limits the adjustment to about one-half pount per hour per cylinder.

A detailed description of one procedure using chlorine cylinders follows: Following the repair of the main, a section of pipe is left out so that a high velocity wash can be obtained to remove small stones and other debris. Two taps are made above the break and two chlorine diffusers are inserted. Chlorine cylinders are then connected to each diffuser. Chlorine is applied to the water used to wash out the line. Upon replacing the length of pipe which is removed for cleaning purposes, a blow-out valve or hydrant is opened at the end of the contaminated area. The pressure in the line should be kept under thirty pounds to permit direct feeding from the cylinders. Once a blood red residual is obtained, the blow-off or hydrant is closed and the line is allowed to stand for four to twelve hours. Then the water is blown off. The blow-off is closed when a residual of about 0.2 to 0.3 p.p.m. is obtained. This system is useful only when the pressure is considerably less than that of the cylinders.

2. Hypochlorinators

Reciporcating pump-type hypochlorinators are applicable to water supplies ranging from 100 to 100,000 gallons per day. Injection pressures may reach 100 p.s.i. Pumps are usually of the diaphragm type pulsating in a rubber, glass or plastic chamber.

3. Gravity Hypochlorite Solution Feeders

Chlorine solution can be fed into an open channel through an orifice tank having a float valve to maintain a constant solution level. The orifice tank has an orifice insert in the valved outlet union. The float is connected to a valve on the discharge line from a stock tank elevated above the orifice tank. Uniformity of feed is obtained by the constant level orifice tank which may be a toilet flush tank. The orifice may be made by inserting a corrosion resisting disc, having a hole and reemed to the proper size of the union.

For maximum simplicity, the hypochlorite solution can be fed with sufficient uniformity without constant level control provided the tank is about ten feet above the orifice discharge. If the variation of the operating level in the tank is restricted to 2 feet, this elevation provides uniform dosage within 5 per cent. The orifice is merely a perforated cap into which a series of liners having various diameter openings may be inserted to vary the feed rate. Control may also be had by means of a stop valve.

REHABILITATION

All flood water and silt should be removed from reservoirs, pumpwells and basements. The affected areas should then be disinfected with a strong chlorine solution (250 to 300 p.p.m.). The floors and side walls should be scrubbed down thoroughly. All water used for scrubbing should then be removed.

Sand filters should be thoroughly washed and sterilized with a strong chlorine solution. When the filters and reservoirs are cleaned and placed in operation, chlorine residuals at the plant of 2 to 3 p.p.m. should be maintained until bacteriological tests show that normal chlorination treatment can be safely resumed.

All flooded or damp motors and other electrical equipment should be thoroughly dried and inspected before re-use. Where necessary, new equipment should be installed.

Flooded motors are reconditioned by heating. This may be done by immersing the motor in hot parafin, placing it in an infra-red cabinet or using other lamp arrangements. After the East Chicago pumping station failure in January, 1949, the flooded motors were first subjected to a current at low amperage and voltage, thus utilizing internal heat of the motors. Then, special lamps were used for the final drying.

New motors may sometimes be dried with a blow torch if handled by an experienced electrician for care is needed to avoid burning of the installation.

QUESTION

Part A

What chlorine residual range should be maintained in all parts of the distribution system when flood water is being pumped from the water works?

Answer - 0.5 to 1.0 p.p.m. by the orthotolidine test.

PART B

What minimum chlorine dose is required to disinfect contaminated mains when a detention time of 4 to 24 hours is used?

Answer - 50 p.p.m. by the orthotolidine test.

BIBLIOGRAPHY

Manual for Water Plant Operators - A. Hirsch
Chemical Publishing Company,
212 Fifth Avenue,
New York 10, N.Y.

Manual of Instruction for Water Treatment Operators,
New York State Department of Health,
Health Education Service,
P.O. Box 7283,
Albany 1, N.Y.

Water Supply Control - Charles Cox
New York State Department of Health,
Health Education Service,
P.O. Box 7283,
Albany 1, N. Y.

Water Filtration
University of Michigan School of Public Health,
Continued Education Service,
109 South Observatory Street,
Ann Arbor, Michigan.

Safety Practice in Water & Sewage Works,
University of Michigan School of Public Health,
Continued Education Service,
109 South Observatory Street,
Ann Arbor, Michigan.

Water Works Practice,
Water & Sewage Works Magazine,
185 North Wabash Avenue,
Chicago, Illinois.

Proceedings of the Annual Short Water Works Courses,
Louisiana State University,
Agricultural and Mechanical College,
Baton Rouge, 3, Louisiana.

Senior Water Works Operators' Course No. 1,
Ontario Water Resources Commission,
801 Bay Street,
Toronto, Ontario.

ONTARIO WATER RESOURCES COMMISSION